For the Royal College of Physicians.

from the Author.

ON

INFLAMMATION

AS A PROCESS OF

ANORMAL NUTRITION.

5

TREATISE

ON

INFLAMMATION

AS A PROCESS OF

ANORMAL NUTRITION.

BY

JOHN HUGHES BENNETT, M.D., F.R.S.E.,

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS;
LECTURER ON THE PRACTICE OF PHYSIC AND ON CLINICAL MEDICINE;
PATHOLOGIST TO THE ROYAL INFIRMARY;
PHYSICIAN TO THE FEVER HOSPITAL, AND TO THE ROYAL DISPENSARY, EDINBURGH;
EXTRAORDINARY MEMBER OF THE ANATOMICAL SOCIETY OF PARIS,
AND OF THE VEREIN FÜR HEILKUNDE IN PRUSSIA;
HONORARY MEMBER OF THE LITERARY AND PHILOSOPHICAL
SOCIETY OF ST ANDREWS, &c. &c.

EDINBURGH:
MACLACHLAN, STEWART, AND CO.,
AND SIMPKIN, MARSHALL, AND CO., LONDON.
MDCCCXLIV.

TO

THE PRESIDENT AND FELLOWS

OF THE

ROYAL COLLEGE OF PHYSICIANS

IN EDINBURGH,

THIS TREATISE,

THE SUBSTANCE OF SIX LECTURES DELIVERED

AT THE

SUMMER EVENING MEETINGS OF THE COLLEGE IN 1843,

IS MOST RESPECTFULLY DEDICATED

BY THE

AUTHOR.

PREFACE.

The following Treatise contains the results of numerous researches on the subject of Inflammation, which have been carried on by the author during the last four years. His first communication was made to the Medico-Chirurgical Society of Edinburgh, in November 1842, and an abstract of it appeared in Cormack's Journal the following month. In the summer of 1843, the views now published were laid before the leading members of the profession in Edinburgh, at the evening meetings of the Royal College of Physicians. The facts from which they are derived also, were then demonstrated under a series of achromatic microscopes. Since then the valuable Reports of Henle and Wharton Jones have been published, which, although they contain many of the facts noticed by the writer, in no way allude to others. Among these may be mentioned the identity in structure between the capillaries and non-voluntary muscular fibre; the structure of lymph in its various forms; the distinction between the plastic and exuda-

tion corpuscles; the identity of the latter with the granular bodies of the colostrum; and the means of distinguishing inflammatory and non-inflammatory softening.

The author has attempted to establish an increased exudation of blood-plasma, as the essential phenomenon of inflammation. He thinks that this view of the subject will introduce much more precision into our notions of its pathology, and be found of considerable value in practice. He has further endeavoured to point out, how all known facts harmonize with this opinion, and how all the phenomena produced are explicable by the cell-doctrine of nutrition now established in science.

If, in performing his task, the author has been enabled to simplify the study of inflammation and its results, or to throw any light upon the obscurity which has hitherto enveloped it, he will be fully compensated.

J. H. BENNETT.

EDINBURGH,
September 1844.

ERRATA.

Page 51, 9th line, instead of *it never assumes* read it assumes.
— 58, 5th line from bottom, instead of *large granulations* read large number.
— 81, 18th line, instead of *the embryo, the vascular, &c.* read the embryo. The vascular, &c.
— 62, 4th line from bottom, instead of *stages* read ways.
— 63, 24th line, instead of *purulent matter cells* read pus cells.
— 66, 4th line, instead of *disposition* read deposition.

ON INFLAMMATION.

INTRODUCTION.

It is daily becoming more and more apparent that the results of *post mortem* examination have ceased to furnish us with facts sufficiently novel and important to advance the study of pathology. The labours of Broussais, Cruveilhier, Lallemand, Andral, and other leaders of the French school, have been keenly disputed, and the truth thus elicited has been embodied amongst the great mass of medical knowledge. In the same manner the researches of Bright, Abercrombie, Carswell, Hope, and others in this country have been well studied, generally understood and confirmed, and the pathologist anxiously looks for some new mode of pushing forward his inquiries. In this juncture the same means by which healthy anatomy and physiology have been advanced, are now employed by the morbid anatomist and pathologist, and organic chemistry and the achromatic microscope furnish him with a key, by the aid of which a new field is thrown open to his investigations.

Researches thus conducted have led to results as unexpected as they are important. In physiology a theory of organization has been shown to apply to all animated nature,—the vegetable as well as animal kingdoms. It has been demonstrated that the humblest and minutest tribes of plants possess the same original structure, as is to be found in the most gigantic trees of the forest, and in animals the same law applies to the production of microscopic infusoria, as to the development of the largest mammiferous

tribes. It is now generally admitted that the functions of nutrition and growth are perfected by means of the formation and development of nucleated cells, and the numerous facts which have tended to elucidate this truth, constitute the basis of the doctrine of cytogenesis.

This theory has been applied with great success to an explanation of the mode in which the normal textures are formed, as well as to the manner in which healthy nutrition and secretion take place. But I do not think that its value, as illustrative of diseased processes, has yet been sufficiently dwelt upon, or that it has been shown to be as universally applicable to the explanation of morbid as of healthy phenomena. If, however, it admit of demonstration that the organic diseases to which animals and vegetables are subject, that the formation of new growths, and the reparation of tissues, are explicable by the same theory, as applies to the development of healthy structure, it must be allowed that a great step will have been made in pathology. Such a consummation, indeed, might enable us to approximate, if not actually reach some primitive or fundamental law which can alone communicate exactitude to medical science.

That the morbid process generally denominated inflammation is in some way or other connected with a perversion or alteration in nutrition, is an idea which has occurred to many pathologists. The general anatomists of Germany even have done much towards determining the mode in which this is accomplished. Still there are many points which have received little attention, and, notwithstanding the vast importance of this fundamental subject in pathology, and the labours of many eminent men, we are still in uncertainty respecting its intimate nature, and the manner in which its products are generated and developed. An attentive study of the numerous works published on this subject, a careful inquiry into the results of modern researches made by means of organic chemistry and the microscope, as well as investigations carried on by myself in connection with it during a period of three years, have induced me to believe that our views of inflammation would be rendered more simple and precise if it could be demonstrated that that process was only a modification of the functions of nutrition, as explained by the doctrine of cytogenesis. I say demonstrated, because although such a view, brought forward as mere hypothesis, might seem probable, it could never, serve without positive facts, to extend our knowledge of the subject. Such, then, is the object of the present memoir. Inflammation is so intimately interwoven with the theory and practice of medicine, it so meets us at the very commencement of our pathological inquiries, as well as in our treatment of disease, that in all ages it has been made the pivot upon which the medical philosophy of the time has re-

volved. Thus any doctrine, capable of explaining the various phenomena which usher in, constitute, and follow this morbid process, cannot but furnish those principles on which medicine, both as a science and an art, must ultimately rest.

I shall discuss the subject under the following heads; 1*st*, Cellular theory of nutrition; 2*d*, The blood; 3*d*, The capillaries; 4*th*, The early phenomena of inflammation; 5*th*, The essential phenomenon of inflammation; 6*th*, Terminations of inflammation; 7*th*, The circumstances influencing the terminations; and *lastly*, the conclusions from the whole.

I. CELLULAR THEORY OF NUTRITION.

The general formation of tissues from cells in vegetables may be shortly described as follows. There is, first, a granular fluid; secondly, a nucleus is formed, which some have described as being made up of an aggregation of these granules, and others, as a corpuscle of a white or dull red colour, enclosing a granule or nucleolus. Upon this nucleus arises a transparent vesicle, at first somewhat resembling the appearance of a watch-glass rising from the dial of a watch, and then the whole constitutes a nucleated cell. The walls of the cell now enlarge. If several lie together they assume a polyhedral form, from the lateral pressure they receive, as in the pith of some plants; fibres are formed from their becoming elongated and splitting up; tubes from the partitions being absorbed whilst the walls remain; and more solid textures from woody or calcareous depositions taking place on their internal walls. After a time, the nucleus disappears, leaving a non-nucleated cell; but it sometimes remains permanently. It must not be supposed, however, that every granular fluid gives rise to a nucleus, every nucleus to a cell, or that every cell assists in forming other textures. Granules, nuclei, and cells, often remain permanently, thus constituting the basis of several fluids and textures. Some cells have their organization completed when fully developed, as in the *Protococcus nivalis*, and *Torula cerivisiæ*.

In animals the same process takes place. The ovum is a nucleated cell of which the germinal spot is the nucleolus, the germinal vesicle the nucleus, and the vitelline membrane the cell wall. Dr Martin Barry has admirably traced the formation of cells within these, from which, as in vegetables, all the animal structures are formed. As in certain tribes of plants some of these nucleated cells are persistent, so in animals, others, such as blood corpuscles, pigment cells of the choroid, fat cells, and those in cartilage are permanent; in others, the cells undergo various modifications in shape, until they ultimately become developed into the different animal structures. Late researches also would indicate that the nuclei are not only persistent in some of the fully formed tissues, but undergo alterations in form, being flattened and elongated.

Reproduction from nucleated cells has been shown to take place

in two ways, 1*st*, by the formation of a fluid between the nucleus and cell wall, in which granules are produced and, subsequently, nuclei and cells, until the original cell wall breaks or disappears, giving exit to the new productions; 2*d*, by new cells arising within the old one, through the division of the nucleus into two or more segments, from each of which a new cell is formed.

This species of growth depends upon the supply of nourishment from without. At the earliest period of development, when the cells are loose, we find them swimming in an albuminous fluid, which contains in solution the elements of nutrition. The cell wall appears to possess a certain vital principle of selection, by means of which these are absorbed. This fluid is called cytoblastema. In the higher plants, when the cells coalesece and undergo transformations, one of the first results of organization is for some of these cells to form a series of canals, by means of which this nutritive fluid is carried to all parts of the organism. In vegetables these vessels, by a species of endosmosis, absorb a nutritive fluid from the soil. This is called sap, and is sent to all parts of the plant. By a species of exosmosis it is again exuded, and constitutes a blastema for the formation and support of nucleated cells. In this way vegetable nutrition is kept up.

Exactly the same process takes place in animals. The ovum, when merely a nucleated cell, is nourished by a vital selective species of endosmosis. In the higher animals, again, one of the first processes is the formation of canals from cells to carry the nutritive fluid to every part of the organism. In oviparous animals a large quantity of material is accumulated within the shell, constituting the yolk and albumen, from which nourishment is derived. In mammiferous animals during utero-gestation this fluid, or cytoblastema, is also obtained by endosmosis from the blood of the parent, and in them, again, by a species of exosmosis, effused for the origin and support of nucleated cells, which rapidly undergo transformations to form the future being.

After birth nutrition is carried on in a similar manner, only that materials are then conveyed into the stomach and intestinal canal, and from these the vessels by an endosmosis, similar to what takes place in plants, absorb a nutritive fluid called chyle, which is ultimately converted into blood.

Thus nutrition in all organized beings consists in the formation of a cytoblastema, in which nucleated cells are formed, which are again ultimately developed into the different textures or made subservient to the function of secretion.*

* M. Mandl has lately attacked the principles of this doctrine on what appear to us very insufficient grounds, and attempted to replace it by a theory of depositions and attractions, of anything but a satisfactory nature. A critical examination of his opinions, however, would lead us too far from the object we have in view. (See

If this doctrine be correct (and it cannot be denied that it is supported by a strong body of evidence) there is one point which demands the serious consideration of every medical practitioner, viz. that a healthy nutrition must depend upon the condition of the nutritive fluid or blastema. This, then, leads us to inquire what are the constituent elements of which it is formed, and what are the conditions necessary to maintain it in a state of integrity.

It has been shown by recent chemical researches, that vegetables and animals are composed of similar proximate principles. These Liebig has divided into nitrogenized and non-nitrogenized. The most important of the nitrogenized elements are fibrine, albumen, and caseine, and these may be still farther reduced into one element, viz. proteine, discovered by Mulder. The more important non-nitrogenized elements are fat, starch, gum, and sugar. These abound in carbon.

Now it has been proved by numerous experiments, that no species of nutrition can proceed unless there be a union of at least one of both classes of elements, and in animals the two which are most readily convertible into nourishment are the albuminous and oily principles. These constitute the basis of every texture. The granules found in every blastema consist of a minute drop of oil, surrounded by a membrane of albumen. Such are the granules of the chyle, the milk, and the yolk of the egg. That they are not loose drops of oil, as some suppose, is proved by their never uniting so long as the membrane which surrounds them remains perfect. I have subjected milk globules to a great force with Chevallier's compressor, and could never make them unite. To abstract the oil from the membrane the latter must be lacerated mechanically, and hence, why the process of churning is necessary to procure butter from cream.

That the globules of milk are real structures is still farther shown, by their possessing the property of endosmosis and exosmosis, as may be proved on the addition of water and syrup. Now these structures may be produced mechanically.

Dr Ascherson of Berlin made the important discovery that, when a drop of fluid fat was brought into contact with fluid albumen, the latter immediately coagulated, and a membrane is formed. I have performed this experiment again and again, and frequently demonstrated the membrane thus produced to others. Shortly after its formation, it becomes stronger and stronger, and apparently contracts into folds. If, after the membrane has been thus produced, the same globules of oil are mixed intimately together by trituration, it is of course broken up, and an emulsion

Manuel d'Anatomie Générale, par M. Mandl, 1843.) Facts to which we shall afterwards allude, undoubtedly show that certain membranes, granules, and filaments may be formed by deposition independent of cellular development. This, however, does not appear to us opposed to the doctrine of *growth* from cells.

formed. But I have observed that an examination with the microscope does not now enable us to detect any shreds of this membrane; we only see globules similar to those contained in the milk, which in like manner are composed of an envelope of albumen enclosing the oil.

It was further shown by Ascherson that the sporules and primary cells in the fungi had a similar composition. The isolated cells of animals, such as those of lymph, blood, and purulent matter, are evidently composed of like principles. They are dissolved in æther and alkalies; the cell wall is made transparent by acetic acid, and they all exhibit the phenomenon of endosmosis and exosmosis. Their composition, then, is essentially the same.

Still the globules in an emulsion or in the milk, though real structures, are not living structures. When and how vitality is stamped upon them is still a mystery, but I believe that they constitute the nucleus of every cell, and that the moment life is imparted to them, a series both of chemical and structural changes takes place. By the first the original element of the nitrogenized principles proteine is converted into fibrine, caseine, or albumen, according to the demands of the organism, and by the second bone, muscle, nerve, and all the various tissues are produced.*

These views are not only important as a matter of theory, they admit of practical application to the treatment of disease. For instance, in scrofulous persons we see nutrition impeded. The nitrogenized elements are in excess; the evacuations even become albuminous and are glairy like white of egg; gradually the albuminous principle of the blood becomes predominant, while the globules are diminished in quantity; at the same time the fatty or carbonized principle disappears, and emaciation takes place; at length albumen is deposited in the textures, constituting tubercular effusions, the destructive effects of which on organs essential to life are ultimately fatal. The whole of this process is evidently one of perverted nutrition; and that this is owing to an absence of the carbonized or oleaginous elements and an excess of the nitrogenized or albuminous, must be evident. The indication of cure, then, under such circumstances, must be to introduce into the system the first named principle, namely, fluid, fat, or oil, in order that it may combine with the excess of albumen, and constitute a healthy blastema for the support of nutrition. The value of this practice is not hypothetical, it has been well established for the last twenty years, long before any theory regarding

* The formation of these globules by the mere union of oil and albumen is cited by Mandl as an objection to the doctrine of cytogenesis, and as favouring his theory of depositions, inasmuch as true cells may be thus formed without either nucleus or nucleolus. The opinion we have advanced above, however, respecting the real character and object of these structures, will perhaps reconcile any seeming discrepancy which may exist regarding them.

it was formed, or the doctrine of cytogenesis heard of. In Germany the animal oils are extensively used in all cases of perverted nutrition, from excess of albumen, they have long held and still hold a prominent place in all the pharmacopœias of Germany, Holland, Sweden, and Denmark, and, at the present day, are continually prescribed by the most eminent practitioners, both physicians and surgeons of those countries. Perhaps there are few articles in the Materia Medica the value of which, in the cases indicated, has been supported by such a mass of incontestible evidence.*

Although the doctrine of cytogenesis undoubtedly embraces a vast number of facts, late researches have shown that it is not so universally applicable as Schwann and his followers have supposed. We have already alluded to the formation of a membrane, and of structures by the union of oil and albumen. The former is very analogous to the sarcolemma, and basement membrane of Bowman, and we have seen a similar one form on the surface of healthy blood during the act of coagulation. Filaments also are deposited in the *liquor sanguinis* of buffy blood which may be seen forming under the microscope independent of cells, as noticed by Gulliver and Addison. Further, the clot frequently presents a purely fibrous structure, and, there is every reason to suppose, as we shall afterwards see, that this fibrous and filamentous texture is subservient to union by the first intention, independent of the formation of nucleated cells. But although the proposition, that every filament is the result of cellular development, requires modification, we have no doubt that all the compound structures, and the essential phenomena of growth, are mainly attributable to the transformation of nucleated cells. Instead, however, of supposing that this alone constitutes the process of formation, facts, in our opinion, indicate that this is combined with the occasional production of membranes, granules, and filaments by means of simple deposition. Perhaps also it may ultimately be seen even more decidedly, that the theory of deposition brought forward by Mandl, should be more or less conjoined with the beautiful doctrine of cytogenesis elaborated by Schleiden and Schwann. If so, future researches must determine the limits which should be ascribed to each, in order that our ideas of formation and growth may be rendered more universally applicable, than by adopting one view to the exclusion of the other.

From all that has preceded it must be evident that the process of nutrition is dependent, on the one hand, upon the blood, and on the other, upon the structures by means of which its nutritive portions are eliminated. These, therefore, it will be necessary to take into consideration.

* See the Writer's Treatise on the *Ol. Jecoris Aselli.*

II. THE BLOOD.

The study of the blood naturally divides itself into that of the solid and that of the fluid portions. The former consists of the different corpuscles which float in the latter, or the blood plasma. We shall consider each of these in succession.

Corpuscles in the Blood.—Three kinds of bodies are found floating in the blood plasma or *liquor sanguinis,* 1*st*, The yellow (commonly called red) corpuscle. 2*d*, The colourless corpuscle; and 3*dly*, minute granules.

The form and character of the yellow corpuscle, as seen under the microscope, is so well known that I need not dwell upon it. Its structure and composition, however, is still a matter of dispute. Most diversified opinions have been held on this subject, all of which, it appears to me, may be reduced to the following. The yellow blood corpuscle has been regarded, 1. as an animalcule, (Kircher, Borelli;) 2. as a globule of oil, (Malpighi;) 3. as composed of six particles, each of which are formed of six lymphatic globules, (Leuwenhoeck;) 4. as a ring enclosing an opening in the centre, (De la Torre) 5. as a vesicle containing a nucleus which moves in it like a pea in a bladder, (Hewson;) 6. as a solid fibrinous body of a biconcave form, (Young, Hodgkin, Lister, Gulliver;) 7. as a homogeneous body in the living vessel which partly coagulates when dead to form a solid centre, (Blainville, Mandl;) 8. as a vesicle containing a nucleus surrounded by air, (Schulz;) 9. as a vesicle simply containing semi-fluid colouring matter, (Donné;) 10. as an organized nucleated cell, (Schwann,) with six nuclei, (Barry;) 11. as a vesicle containing a nucleus attached to it by its poles, surrounded by a coloured fluid, (Rees, Lane;) 12. and lastly, as a body containing a spiral filament, the elementary texture of all tissues, (Barry.)

On taking into consideration the structure of the yellow corpuscle, we must consider its physical properties, for it is evident that no view of its formation can be correct if it do not harmonize with the known facts regarding it. Thus, the yellow blood corpuscle is, 1*st*, highly elastic. It may be seen when examining structures running between solid or agglomerated masses, elongating itself, and after having passed the obstruction rapidly

regaining its original circular form. *2d*, It exhibits the phenomenon of endosmosis and exosmosis. Water causes it to swell, to lose the form of a disk, and to become colourless and globular. Syrup, on the other hand, causes it to contract and shrivel up. *3d*, The addition of weak acetic acid dissolves, or renders very transparent, its outer wall, whilst its central portion becomes insolated and prominent. These facts must be acknowledged by every histologist who has carefully examined these corpuscles, and it must be evident that they are totally opposed to the opinions of Kircher, Borelli, Malpighi, Leewenhoeck, De la Torre, Young, Hodgkin, Lister, and Gulliver. On the other hand, they are more or less in harmony with the views of Hewson, Blainville, Mandl, Schulz, Donné, Schwann, Rees, Lane, and Barry.

A criticism of the different opinions these observers have brought forward would carry us too far; suffice it to say that a careful examination of them, in conjunction with numerous observations of my own, have convinced me that the view of Schwann combines in itself all the facts with which we are acquainted regarding the corpuscle, viz. that it is a nucleated cell, subject to the same vital laws of growth and decay as those of similar isolated and organized structures. All the observations which have been made with respect to its development agree with this view of the subject. Moreover, I have occasionally, like Donné, seen the outer wall break, the fluid escape, and the shrivelled-up membrane remain. Like Barry, I have seen these corpuscles undergo rapid changes in form, sometimes appearing as if the nucleus were attached to the side, at others, the edges serrated, and at others, the whole structure oval, square, or crescentic.* Like him also, and Quekkett, I have occasionally seen the cell enclose granules, which are given off on the rupture of its wall, and sometimes I have seen in the nucleus of the corpuscle, an enclosed granule or nucleolus. All these facts support the view of its cellular origin and nature, and we may consider this structure as composed, in the majority of instances, of a nucleus, a cell wall, and a fluid interposed between them.

The steps by which these bodies are formed in the adult, and their ultimate destination, have not yet been accurately traced. It is very probable, however, that they will be found to obey the same laws as govern the development of organized cells in general. The granules of the chyle entering the torrent of the circulation probably constitute the nuclei of these bodies, which assimilating from the *liquor sanguinis* as a blastema, the elements of nutrition undergo further changes to constitute the perfect nucleated

* Indeed these bodies may be said to undergo endless varieties of shape, under different circumstances.

cell. After a time it is likely that they are again dissolved in the blood-plasma. In this way the yellow corpuscle and *liquor sanguinis* may be said to be mutually convertible into each other.

With respect to the functions of these bodies, I consider that the theory of Liebig perfectly agrees with most of the pathological facts with which we are acquainted, and even with what we know of the formation of these bodies. He shows that they are the only structures in the blood which contain iron, and to this circumstance we must attribute their colour. Whether, however, the oxidized compound of iron be dissolved in the fluid existing between the nucleus and cell wall, or exist in a more solid form lining the latter, has not yet been demonstrated. Most probably the first opinion is the correct one, as asserted by Rees and Lane. At all events, we may, with Liebig, regard the yellow corpuscles of the blood as the carriers of oxygen, which they absorb in the lungs and give off in the capillaries. Hence two processes of oxidation are continually going on: by the one, the constant temperature of the lungs, and by the other, the heat of the rest of the body is maintained. For the facts and observations from which this theory is deduced, I must refer to the work of Liebig itself.

The colourless corpuscle has received a much less share of attention than the one just noticed. In the Mammalia they were first seen by M. Mandl. Their number in man differs in different individuals. I have sometimes seen them very numerous, whilst at others scarcely one can be discovered. I have frequently found also that whilst aortic blood is free from these bodies, that of the *vena cava* in the same subject contains great quantities of them. Whether they are similar to the lymph corpuscles in the blood of reptiles, described by Spallanzani and Müller, it is difficult to determine. They are not of the same size; and it is worthy of remark, that in reptiles the yellow corpuscle is the larger, the white one is the smaller. In man it is the reverse. In reptiles we can see them moving in the living vessel. This of course has never been observed in man, nor, so far as I am aware, in the Mammalia, although the bat's wing offers a favourable means for observation. There is one difficulty, however, with respect to their existence in the blood of mammals, viz. that from their size they could not pass through a great part of the capillary system. Are we then to believe with Mandl, that they are fibrinous globules, that is, the fibrin coagulated on the object glass? Such a conclusion appears to me opposed by the fact, that they possess cell walls, contain granules, and exhibit a distinct nucleus on the addition of acetic acid. They are, therefore, organized cells. On a superficial examination they resemble pus globules, and have no doubt been often mistaken for these corpuscles.

Besides the structures just alluded to, minute granules are found in the blood, resembling those of chyle, and such as are found within all organized cells. Whether they are the same granules seen in the chyle which have undergone no further change, or whether they are the granules found in the white and occasionally in the yellow blood corpuscle, is still undetermined. No doubt, however, that many of these granules exist in the blood, varying in number and size in different circumstances even in the same individual. In this, then, as in every other blastema for the support of nucleated cells, we see granules and corpuscles in different stages of formation.

It has been thought by Donné, and others (Barry,) that these three kinds of bodies are only different stages of one growth. That one or more of the granules unite to constitute a nucleus; but whether the yellow or the white corpuscle is the next or the ultimate stage of growth is not determined. There can be little doubt that the existence of these different corpuscles in one fluid are connected with some such explanation, and it further seems probable from an analogy to the development of cells in general, that the white corpuscle is the last stage of the process. It has already been stated that granules are occasionally seen within the yellow corpuscle, and we have only to suppose these increased, the whole structure enlarged, and an absence of colour to constitute the white one. That they are so few in number when compared to the yellow corpuscles is dependent possibly on a large number of the latter being dissolved. We may, however, readily conceive that some escape and undergo further development.

Let us now consider the fluid part of the blood, the *liquor sanguinis* or *blood plasma*.—This fluid, when seen in the vessels of a living animal, appears perfectly transparent. Under certain circumstances it is known to possess the property of coagulation, that is to say, the fibrinous portion becomes separated from the albuminous in a solid form. This process of coagulation is diffecent according as it takes place, removed from the body, or in contact with the living tissues.

It is now well known that the corpuscles of the blood take no active part in the formation of the clot. They are merely entangled in the meshes of the fibrin, and impart their colour to it. They may, however, be separated from it mechanically by washing or by stirring the blood with rods while in the act of coagulation. In some states of the blood the corpuscles sink to the bottom of the vessel, and a buffy coat is formed. This is favoured by every circumstance which retards the coagulation. Hence why a large opening in the vein and a deep vessel induce, whilst a small interrupted stream, a shallow vessel, and a cool atmosphere retard the formation of the buffy coat.

It has long been supposed that this phenemenon is especially

connected with an inflammatory state. Piorry even calls it hematitis or inflammation of the blood. That the buffy coat is common in acute inflammations cannot be questioned, and it would appear to result from the greater specific gravity of the corpuscles, as compared with that of the *liquor sanguinis* in such cases. This was first pointed out by Jurin, and confirmed by J. Hunter and J. Davy. It would also seem from the experiments of Mandl, that, notwithstanding the greater quantity of fibrin found in inflammatory blood, that its specific gravity is somewhat lower than in health, and the observations of Nasse, Thackrah, Scudamore, Babington, and others support the same conclusion.* Further, it is well known that a buffy coat often appears in the third cup of blood taken, although not in the first or second. This has more especially been observed in rheumatism. Here the blood has been too dense and tenacious to allow the easy deposition of the yellow corpuscles; but no sooner is it rendered somewhat thinner by venesection than the globules subside more quickly, and a colourless layer of fibrin is formed on the surface.

It has been shown by Andral and Gavarret that in inflammations an excess of fibrin exists in the blood, and that the proportion is not only increased relatively to the globules and its other constituents, but as regards the amount of this fluid in the body. A buffy coat, however, may also exist on the clot of anemic patients, especially of chlorotics. In such cases the yellow globules are diminished in quantity, whilst the amount of fibrin remains normal. Here, then, a similar disproportion between the fibrin and globules takes place, causing a like result, although the pathological state is very different. A buffy coat, therefore, although frequent in inflammations, cannot be considered as peculiar to them.

On examining a portion of the clot under the microscope, it will be found to be made up of minute filaments interlacing each other and mixed with the corpuscles of the blood, as was first pointed out by Mr Gulliver. The mode in which these filaments are deposited is well described by Mr Addison. The process is best seen in blood removed from a man labouring under acute pleuritis. I have frequently had opportunities of confirming the observations of Mr Addison, and of seeing these filaments form under the microscope. The process is somewhat analogous to crystallization, except that no regular forms are produced, and the filaments float loose in the serum, or are more or less interlaced with each other.

Mr Gulliver states that nucleated corpuscles exist in the colourless clot, and supposes that in coagulating such corpuscles are

* Nasse and Wharton Jones attribute the buffy coat to an increased attraction existing between the yellow corpuscles. The latter supposes that they form a net or sponge-work, the contraction of which squeezes out the colourless *liquor sanguinis*.

formed. Now coagulation is the last vital act of the blood, and it would certainly be surprising if new growths were to spring up when life is about to become extinct. The formation of filaments is simply an act of deposition, and is completed in a few moments. A nucleated cell, on the other hand, is the result of growth, must pass through regular stages, and can scarcely be conceived to be formed so rapidly. I have in vain looked for corpuscles that might be attributed to such a source. But I have frequently seen the yellow corpuscles deprived of their colouring matter intimately mixed with the filaments, the which, it appears to me, must have been mistaken for nucleated cells proper to the clot.* I have frequently endeavoured, by maceration and washing, to separate the blood-globules from portions of clot; but although I have readily made the latter colourless, yet I never could succeed in entirely removing all the corpuscles.†

Coagulation sometimes takes place within the vessels during life, causing more or less obstruction, or it is the result of the formation of aneurismal pouches. In either case portions of the clot are often found colourless from the readiness with which the yellow corpuscles are precipitated. On the other hand, coagulated *liquor sanguinis*, when exuded into the living textures, presents appearances and undergoes changes, which will be more particularly alluded to in a subsequent part of this memoir.

As regards the function of the *liquor sanguinis* it is entirely subservient to nutrition. During life, portions of it are continually exuding through the capillary vessels, and undergoing changes by means of which the texture and secretions are constantly forming. It holds in solution all the principles essential to the constitution of these, which are elaborated in different organs through the medium of the minute blood-vessels. Whilst, on the one hand, it is continually receiving, from the result of digestion, new matter, so, on the other, it is always dispensing this in an altered form to every part of the organism to meet the wants of the economy.

We find, then, that the blood consists of a solid and of a fluid portion, and may be regarded as continually carrying on two great systems of operations. The solid particles are subservient to the production of animal heat, whilst the fluid portion is subservient to the function of nutrition. These two operations are intimately connected with one another. Without a certain temperature, as we shall afterwards see, the growth of organized beings cannot proceed, and without the existence of nutritive elements,

* The colourless corpuscles found in the clot, which Andral describes as *globules blancs* after the addition of sulphate of soda, are, in my opinion, changed yellow corpuscles, and not the granular bodies destitute of colour found in healthy blood.

† Of course the corpuscles found in exuded lymph, from inflammation, are not to be confounded with those here alluded to.

capable of undergoing chemical transformation, animal heat cannot be maintained.

In the performance of these important operations the blood itself is dependent on a system of vessels distributed through the organism. Whilst the first furnishes the essential material, the latter is the apparatus through whose agency the effects are produced. Thus we are led to a consideration of the capillaries.

III. THE CAPILLARIES.

To the naked eye blood-vessels appear to be formed of three coats. 1*st*, The internal or serous; 2*d*, the middle or fibrous; and 3*d*, the external or cellular. A more minute examination has enabled the histologist following Henle to demonstrate the existence of six layers, each of which may readily be distinguished by its intimate texture. They may be enumerated as follows, proceeding from within outwards. 1. The internal layer which presents all the characters of pavement epithelium. 2. The second layer is a transparent, delicate, and fragile membrane, which easily rolls upon itself. It is distinguished by long, occasionally branched filaments, running transversely, with round or oval openings of various sizes perforating the layer. It is occasionally absent. 3. The third layer is characterized by longitudinal lines which are in no way changed by acetic acid. It is formed of one and sometimes of several membranes. 4. The fourth layer is characterized by short transverse fibres, which alternate with each other. It is much developed in large vessels, and constitutes the principal portion of what is called the middle coat. 5. The fifth layer is only found in the large arteries, and is, in point of fact, true elastic tissue. 6. The sixth layer is composed of cellular tissue, the fibres of which are arranged longitudinally, having scattered here and there persistent nuclei.

The satisfactory demonstration of these different layers requires great care. Some are better seen in the arteries than in the veins, or in vessels of a particular size. For all the necessary information on this subject I must refer to Henle. The smallest twig of a vessel in the mesentery of a rabbit, rendered transparent by weak acetic acid, and examined under a power of 500 linear diameters, will immediately convince any one of the accuracy of his description.

As the vessels approach the periphery the coats become fewer and fewer in number. The cellular, longitudinal, and transverse layers remain in very minute vessels. At length the two first also disappear, and in the true capillary or intermediate vessel we have nothing but the remains of the transverse. It is composed of a simple transparent, yet very firm membrane, without the smallest opening, studded at irregular intervals with nuclei of various shapes.

These are sometimes round, at others oval, and occasionally approaching a square form. I have found it very easy to demonstrate these vessels on subjecting a portion of *pia mater* to the microscope. In the rabbit and mouse their characters are very distinct and beautifully defined.

In the numerous demonstrations I have made of these structures, I was struck with the resemblance which the capillary vessel presented to the fibres of non-voluntary muscles. These, it is well known, are described by histologists to be composed of bands, with nuclei scattered at irregular intervals in their substance. I subsequently discovered that, if the mucous coat be carefully removed from a portion of intestine, (say in the rabbit,) and the remaining structure rendered transparent by acetic acid, a longitudinal and transverse coat, with longitudinal and transverse lines, formed by elongated nuclei, are apparent as in the coats of arteries. In short, the two structures in some demonstrations were so similar, that I should have had some difficulty in recognizing one from the other, were the microscopic examinations above attended to. Repeated examination of this fact, as well as numerous observations on the organic muscular fibre, have led me to the conclusion, that no structural difference exists between what is called the muscular coat in the intestines, and that constituting the third and fourth layers in arteries, as previously described. Neither does any essential difference exist between these last and the ultimate texture of the capillaries. If this opinion be correct, then it will be natural to suppose that their function is also similar.

The question of the muscular structure of arteries has been long a subject of dispute. Latterly, however, physiologists have, for the most part, concluded that the arteries are not muscular, although they all acknowledge that the capillaries possess undoubted contractility. Now, if this property depend on the so-called muscular coat in the intestinal walls, why should not the contractility in the capillaries be connected with a structure which we have demonstrated to be similar. We are certainly inclined to hold this opinion, the which is rendered more probable from the fact, that the contractility is more evident and powerful where the structure is most free from all others. In the larger arteries and veins, the layer of epithelium, the fibrous and cellular coats more or less retard its action, and we have no evidence of powerful contraction in those vessels. In the capillaries, on the other hand, where this structure constitutes the whole of the vascular wall, the contraction is very powerful, as is demonstrated by a crowd of physiological and pathological facts.

The term muscular fibres, as applied to this structure, gives rise to very erroneous notions. Persons naturally conceive that some relation exists between voluntary and non-voluntary muscle, whereas no two elements can be more distinct. The fibres seen

running longitudinally and transversely, as in the intestinal coats; the fibres of the bladder, stomach, &c. have no analogy whatever with the striated fasciculi of voluntary muscle. Their mode of contraction, also, is perfectly unknown. The fact, however, viz. that the structure hitherto called non-voluntary muscle is the same in the contractile coat of the muscles and intestines, the middle coat of the arteries and in the capillaries, leaves very little doubt in my mind, that the vital contractility possessed by all these tissues is the same, and dependent on the same causes.

The mode in which the capillaries are arranged merit great attention. The term capillary derived from the Latin *capillus*, a hair, was formerly only intended to convey the meaning of a fine vessel. It is now found to be very vague. Most of the vessels constituting the pheripheral vascular system are much smaller than the human hair, some even not above one-sixth or one-tenth of its size. The smallest are those which will only permit one blood globule to pass through it in single file. These vessels are formed of the simple structure formerly described. Others are much larger, and allow two or more globules to pass abreast, and are composed of two layers. Berres and Hyrtl have distinguished these two kinds of vessels from each other, calling the latter capillaries, and the former intermediate vessels. According to them we have arterial capillaries and venous capillaries, and an intermediate system connecting the two. This distinction, which is supported by the structure, and probably the function, is certainly deserving attention.

A description of the various net-works which the capillary and intermediate vessels form, would be foreign to the object of this memoir. I must content myself with referring to the works of Berres, Hyrtl, and Krause. Suffice it to say, that, although the distinctions made by the first anatomist are perhaps unnecessarily numerous, still most characteristic differences really exist, indeed so much so as to enable one readily to detect the tissue or organ, simply from an inspection of its vascular arrangement. Further, I think it can scarcely be denied that the arrangement of the minute vessels is intimately connected with the peculiar structure and functions of the organs which they supply. The crossed twig in cellular tissue; the straight capillaries with their intermediate vessels at right angles, in muscle; their peculiar arrangement in the cortical substance of the kidney, in the liver, &c., all lead to the supposition that the disposition of these vessels is intimately connected with the distinctive results of nutrition and secretion in various localities.

The more specific office of the capillaries and intermediate vessels is evidently, 1*st*, so to subdivide the blood that it may reach every portion of the organism, and enable its corpuscles to perform their function. 2*d*, to offer a membrane by means of

which exosmosis and endosmosis may be effected. What the connection may be between the vital properties of those vessels and the exudation of blood plasma it is difficult to determine. We may remark, however, that the delicate homogeneous structure they present, admirably fits them for acting as fine filters subjected to vital laws,—retaining the solid corpuscles and granules, and allowing only the fluid portions to transude. How far the circulation is influenced by the contractility of the capillaries is still a matter of inquiry.

From these considerations the importance of the capillaries, as connected with nutrition, will become apparent. So long as they only permit that amount of blood plasma to exude which is capable of supplying the quantity dissipated by waste, so long they may be considered as performing their functions in a normal manner. But when circumstances induce such a change in them that the amount of exudation is materially diminished or increased, then an *anormal* state is occasioned. If the amount be diminished, atrophy will be produced, if it be increased, that peculiar pathological change, hitherto denominated inflammation, is constituted. The steps by which this is occasioned we shall now proceed to consider.

IV. THE EARLY PHENOMENA OF INFLAMMATION.

Numerous researches and experiments have determined that the phenomena of inflammation, as observed under the microscope, take place in the following order. 1*st*, The capillary vessels are narrowed, and the blood flows through them with greater rapidity. 2*d*, The same vessels become enlarged, and the current of blood is slower, although even. 3*d*, The flow of blood becomes irregular, it oscillates, that is, goes forwards and backwards, and sometimes stops for a period, and then resumes its course. 4*th*, All motion of the blood ceases, and the vessel appears fully distended. 5*th*, and *lastly*, the blood is either effused by rupture into the surrounding tissues, or the *liquor sanguinis* is exuded without rupture. These different phenomena produce the more evident appearances of redness, heat, pain, and swelling.

The first step in the process, viz. narrowing of the capillaries, is readily demonstrated on the addition of acetic acid to the web of the frog's foot. If the acid be weak, the phenomena occur more slowly and gradually. If it be very concentrated, the phenomenon is not observed, or it passes so quickly into complete stoppage of blood, as to be imperceptible. Although we cannot see these changes in man under the microscope, certain appearances indicate that the same phenomena occur. The operations of the mind, for instance, as fear and fright, and the application of cold, produce paleness of the skin; an effect which can only arise from contraction of the capillaries, and a diminution of the quantity of blood they contain. In the majority of instances, also, this paleness is succeeded by increased redness, the same result as follows from direct experiment on the web of the frog's foot, constituting the second step of the process. This depends on the enlargement of the capillaries and the greater quantity of blood they contain.

The variation in the size of, and amount of blood in the capillaries is conjoined with changes in the movement of that fluid. Whilst the vessels are contracted the blood may be seen to be flowing with increased velocity. Indeed, so far as my observations go, the increased swiftness of the blood is the principal proof of diminution in the calibre of the vessel. After a time, the blood flows

more and more slowly, without, however, the vessel being obstructed; it then oscillates, that is, moves forwards and backwards, or makes a pause, evidently synchronous with the ventricular diastole of the heart. At length the vessel appears quite distended with yellow corpuscles, and all movement ceases.

Again, these changes in the movement of the blood induce variations in the relation which the blood corpuscles bear to each other, and to the walls of the vessel. In the natural circulation of the frog's foot, the yellow corpuscle may be seen rolling forward in the centre of the tube, whilst on each side a clear space is left, only filled with *liquor sanguinis,* and a few lymph corpuscles. There are evidently two currents, the centre one very rapid, that at the sides (in the lymph spaces, as they are called,) very slow. The yellow corpuscles are hurried forward in the first, occasionally mixed with some lymph corpuscles. These latter, however, may frequently be seen clinging to the sides of the vessel, or slowly proceeding a short distance down the tube in the lymph space, and then again stopping. Occasionally they get into the central torrent, when they start off with great velocity and accompany the yellow corpuscles. When the capillaries enlarge, however, the central column may be seen to enlarge also, and gradually approach the sides of the tube, thus encroaching on the lymph spaces. The slower the motion of the blood, the closer they come, until at length they reach the sides of the vessel, and become compressed and changed in form; the vessel now is completely distended with yellow corpuscles, the original form of which can no longer be discovered. Thus congestion is occasioned.

If the morbid process continue the vessel may burst, causing hemorrhage, or the serum and *liquor sanguinis* become effused into the surrounding textures. The exudation of the latter constitutes the essential phenomenon of inflammation. Before, however, proceeding to a consideration of this, let us inquire into the supposed causes of the previous phenomena, or what is usually denominated the *theory of inflammation.*

The whole of this subject has been rendered exceedingly complex and difficult, not only from the numerous theories advanced, but from the many false facts by which some of these have been supported. Within the last few years, also, such great advance has been made in our knowledge of the minute structure of different organs, of the functions they perform, and of the operations of the nervous system by reflex action, that a review of the whole seems necessary. Such is my object with respect to this part of the subject, and I need only premise that it is not so much novelty, as condensation and clearness, which will be kept in view. In the account to be given I shall in a great measure follow the views of Alison and Vogel, more especially of the latter.

The first anormal change in inflammation discoverable by the microscope is without doubt contraction of the capillaries, whilst the blood flows through them more rapidly. Here the following reflections naturally arise. The diminution in the calibre of the capillaries must be caused either by the contractility of their walls primarily, or by the contraction of the parenchyma which surrounds them. In the latter case they would be narrowed secondarily.

Now it is difficult from observation to separate with precision one of these processes from the other. The walls of the capillaries are so intimately connected with the surrounding parenchyma, that it will be evident contraction of the capillaries must necessarily draw the parenchyma after it, and, on the other hand, contraction of the parenchyma must occasion diminution of the calibre of the capillaries.

An observation of what occurs in lax parts, where the parenchyma and vessels are not so intimately connected, as in the vessels of the mesentery, supports the view of inherent contractions in the capillaries. At least it cannot readily be understood how, in a membrane so delicate, where the parenchyma is so loose, its being primarily affected, can produce the regular contractions observed in the vessels. This view is strengthened if the ultimate structure if the capillaries be really identical with that of non-voluntary muscle found in other tissues, as previously stated. This would readily explain the well known fact of the capillaries being more contractile than any other portion of the vascular system,—a circumstance otherwise certainly very mysterious.

On the other hand, many observations support the view that diminution in the calibre of the capillaries depends upon contraction of the parenchyma or structures which surround them. For instance the corrugation of the skin, the so-called *cutis anserina*, from the application of cold. Here evidently not only are the capillaries contracted, as is proved from the paleness of the skin, but also the elementary fibres of the skin itself, which, by their pressure on the hair bulbs, may occasion this phenomenon. Here we cannot suppose that contraction of the capillaries alone would be sufficient to drag mechanically the primitive filaments of the parenchyma, which so curiously interlace the hair bulbs. Every one who has microscopically examined the skin, and convinced himself of its great elasticity, will certainly share this opinion.

Very probably, then, both causes may act sometimes separately, sometimes together, and we may state that "diminution in the size of the capillaries follows either from an inherent contraction of their walls, or secondarily, as the result of contraction in the parenchyma of an organ, or lastly, from both these causes together." (Vogel.)

The next question that arises, is, how are these effects in their turn produced? In reply the following reflections suggest themselves.

The causes producing the contraction of the capillaries, whether acting upon the vessels themselves or upon the surrounding parenchyma, operate either directly or indirectly. If directly upon the tissues, they may be purely mechanical, purely chemical, or purely vital. If indirectly, it is through the medium of the nervous system, and thus the causes may act directly by means of the peripheral nerves, or indirectly, that is, by reflex action. Let us now examine how far facts indicate which of these views is correct.

We observe paleness or contraction of the capillaries to be caused in man by purely mental causes, such as anger, disgust, fear, or anxiety. In such cases a local operation of the causes on the nerves of the periphery, or on the vascular walls or parenchyma, is not to be thought of. The cause here evidently originates in the nervous centres, and acts secondarily on the nerves distributed to the vascular walls or parenchyma. It must also be evident that the change thus occasioned must be in its nature *vital.*

But the same effect is produced by the topical application of cold and reagents, such as vinegar, or by friction. Either of these can produce paleness of the skin. Here, then, if any effect be produced on the peripheral nerves it is not reflex but direct.

But it may be contended that the effect so occasioned is of a chemical or mechanical nature. But observation tells us that the contraction is followed by dilatation. Now it is impossible that the same stimulus, if it act by physical laws, should produce two opposite results, first contraction and then dilatation. Thus, then, we are necessarily led to the conclusion, that the contraction of the capillary vessels preceding inflammation is in its nature *always vital.*

With the contraction of the capillaries we have seen that there is also a more rapid current of blood through the vessels affected. This may be explained on the hydraulic principle, that when a certain quantity of fluid is driven forward with a certain force through a tube, and the tube is narrowed while the propelling force remains the same, the fluid must necessarily flow quicker. The value of this explanation, however, is lessened on regarding the collateral circulation. The resistance to the flow of blood in the narrowed vessels will, according to physical laws, be so much the more the greater the swiftness and the narrower the tubes. But those capillaries which are not affected, as they offer less resistance than those which are, must proportionally receive more blood than formerly, whereby necessarily the swiftness of the current of blood in the surrounding vessels must be diminished. The influence thus produced, however, cannot be estimated, and we are therefore compelled to conclude that the increased swiftness

of the current of blood in the contracted capillaries is the physical result of a narrowing of their calibres.

We have now to inquire what are the causes producing enlargement of the capillaries, and a slower movement of the blood in them—constituting congestion.

It is a widely spread opinion, that in congestion the affected parts have more blood conducted to them than natural. But this view cannot be supported by direct observation, which only warrants our stating that the affected part *holds* more blood than usual, not that an increased quantity of this fluid passes through a given part in the same space of time. On the contrary, observation tells us that the blood in enlarged capillaries flows slower than natural, and thus opposes rather than favours the hypothesis of determination.

It is true, however, that the pulse of arteries leading to inflamed parts is fuller and stronger than natural, and that it must consequently receive and transmit more blood than in a normal state. But observation at the same time shows that the increased beating of particular arteries does not in general precede the congestion, but follows it. Although, therefore, this increased arterial action may keep up and augment a congestion once formed, it cannot be considered as its first cause. This phenomenon, which has been considered the proof of increased determination, is most probably then a propagation of the state of the capillaries to the arteries—is secondary and not primary.

That dilatation as well as contraction of the capillaries depend upon their possessing an innate vital action, may be proved by nearly the same arguments. For instance, it may be caused by mental emotions, as shame, joy, anger, and the like, and may, therefore, under certain circumstances, be dependent on the nervous centres. It may also be produced by the topical application of heat, friction, and chemical stimulants. That these act, however, on the vital properties of the tissues and not physically, is proved by the paleness and vascular contraction they first occasion. Here, again, as no physical cause by its continued operation can produce two opposite effects, the phenomenon must be vital. It may therefore be said, that "the dilatation of the capillaries in congestion is an innate vital action of these vessels, resulting from causes acting upon the nervous system, either direct on the peripheral nerves, or indirect from the nervous centres—possibly also, upon a direct operation of the cause upon the vascular walls." (Vogel.)

The slow movement of the blood in congestion is explained by the same physical law as is applicable to its increased rapidity. For the same reasons that, when the calibre of the vessel is diminished, the current is quick, so when it is enlarged the current must

be slow. In the same manner also, the collateral circulation and the increased determination in the neighbouring arteries which subsequently arises can only allow the physical cause to operate to a certain extent. Other influences come into operation which affect its movement, as we shall immediately see.

Now, if we compare the narrowing and dilatation of the capillaries with the phenomena occurring in muscular parts, we need not wonder that Cullen and others should have dwelt so much upon the doctrine of spasm of the extreme vessels. In muscles we see relaxation taking place as a natural result of spasm, and what occurs in the capillaries is identically the same. Moreover, the action in both cases is produced by similar causes, that is, may depend upon local irritation, or reflex action through the medium of the nervous centres.

It may be said, therefore, that congestion is owing, first, to the operation of a diseased cause, producing transient spasm, then relaxation or paralysis of the capillaries. In many cases, however, the spasm soon passes off, or is entirely wanting, and relaxation or paralysis appears at once. In this way all the phenomena of congestion are readily explained, the increased determination of blood consisting only in the propagation of the relaxation to the arteries.

The next series of changes which require explanation consists of the oscillation in the column of blood, the encroachment on the lymph spaces, complete repletion of the vessel, with blood globules, and lastly, total cessation of all movement.

It is very difficult to determine the cause of oscillation in the column of blood. It may be remarked, however, that this phenomenon has only been observed in the smaller animals, which are held fast under the microscope. Even here the oscillation is not invariably seen to precede the stoppage. It is most frequently observed, also, when the animal is very weak, or has fallen into asphyxia. Under such circumstances the energy of the heart and large vessels is evidently diminished, and the blood will be propelled with less force than usual against the capillaries, and either stop for a moment, or flow backwards during the diastole of the heart. It is probable, therefore, that the oscillation does not essentially belong to inflammation, but rather depends upon the general weakness of the animal. This opinion is strengthened by a fact I have frequently observed, viz. that, if whilst examining the circulation in the web of the frog's foot, the animal struggle violently, the motion of the blood is arrested. As the animal recovers from the exertion, the circulation is again gradually re-established, the column first oscillating, and then running in a continuous stream. This is more apparent if the subject of experiment be young.

Let us now inquire the cause of stoppage of the blood. It is of great importance that this should be determined correctly.

We have seen that dilatation of the capillaries can only explain the retarded movement of the blood by physical laws. Dilatation of these vessels alone cannot, without the operation of other causes, produce stoppage, for should the tone of the arteries be lost, yet the heart and large trunks would still possess sufficient power to carry on the circulation. Besides, we have seen that the relaxed arteries in the neighbourhood of the affected part receive and conduct more blood than usual; a circumstance which should prevent retardation of the current did it depend merely on physical laws. Hence, it cannot be conceived how simple dilatation of the capillaries can induce a stoppage of the blood.

This effect has been attributed to obstruction. In a dilated capillary it is possible that there, where only one blood corpuscle passed, now more, two or three abreast may pass; that these, by pressure, may receive a flattened form, and thus become wedged together, so as to occasion in the current of blood a mechanical obstruction which, once produced, may extend further. This mode of explanation, however, is opposed to observation; for 1*st*, The stoppage of blood does not, as is supposed, proceed from one point; it takes place over a portion of the capillary system more or less extensive at the same time; 2*d*, The lymph space near the walls of the capillaries is still evident when the blood moves slowly, and only disappears after the stoppage has taken place. Now, did obstruction arise from wedging of the blood corpuscles, it ought to be the reverse.*

We cannot, then, attribute the stoppage to this mechanical cause. No doubt, however, when once produced it may tend to keep up the obstruction. It then becomes passive, and resembles mechanical and other forms of obstruction by simple pressure.

Again, the stoppage has been attributed to an impediment to the return of the venous blood. But such an opinion is also opposed to observation; for 1*st*, veins which come from inflamed parts allow, as far as can be ascertained, the same quantity of blood to pass as usual; 2*d*, the venous ends of the capillaries and smaller veins are rather widened than narrowed in inflamed parts, and it is not to be conceived what circumstance should impede the

* Whilst these pages are going through the press, I have seen the "Principles of Medicine," just published by Professor Williams of London, I find that he confirms the observation of Mr Addison, viz. that the number of lymph corpuscles may be increased within the vessels of the frog's web by irritation. He conceives that these corpuscles, assisted by diminished elasticity of the vascular walls, produce the obstruction, (p. 214, par. 419.) Without denying the occasional accumulation of these lymph corpuscles in certain vessels, I must record my conviction that inflammation, accompanied by complete obstruction, may be frequently occasioned independent of any such phenomenon.

backward flow of the blood in those vessels ; *3d*, observation shows that, when a true stoppage takes place from impediment in the veins, the phenomena are quite different from those in inflammatory obstruction. For instance, when abdominal tumours press upon and obstruct the large venous trunks, we may certainly have effusions of serum, constituting œdema, but none of the phenomena of inflammation. Thus, then, the cause of stoppage cannot be sought for in the veins.

Now, as it has been shown that the power which retains the blood does not consist in material impediments, there only remains to be advanced, that the phenomenon is vital, depending upon an increased attraction between the blood and the surrounding parts.

This increased attraction can only originate in a change of the vital force. 1. of the blood; 2. of the surrounding parts; and 3. of both these elements together.

It may be objected to the view which places the change of vital force in the blood, that, if this be the cause of stoppage, why should not the effect be more universal ? Again, if the blood in inflammation be always affected so as to cause stoppage in the capillaries of a part, then we must suppose that the whole mass of blood is influenced by the smallest wound, such as that made by a razor for instance, which would be eminently absurd. We are not warranted, therefore, in ascribing the cause of stoppage to the blood alone, and although changes do occur in its chemical constitution, facts prove that this is often confined to a very limited portion.

In the same manner it may be shown that although, as we have seen, the vital properties of the parenchyma are undoubtedly affected in inflammation, the cause of stoppage cannot be exclusively attributed to the attraction it may be supposed to exert. Let us remember the researches of Andral, Gavarret, and Simon, who have shown that in acute rheumatism and pleurisy for instance, the blood contains an increased quantity of fibrin. Now, when we consider with what facility in acute rheumatism inflammation in the different joints is occasioned from very trifling causes, we are certainly warranted in ascribing a portion of the morbid influence to the blood. The same holds in every case where we seek the cause of inflammation, as has been done for a long time in what is called an inflammatory diathesis.

We are, therefore, compelled to conclude, that the most satisfactory theory which can be advanced explanatory of the facts we have described, is one which conceives the existence of an increased mutual attraction between the blood and surrounding parenchyma. Hence may be explained the gradual approach of the blood corpuscles to the sides of the vessels; the encroachment on the lymph

spaces and subsequent stoppage, the effusions and exudations where the fluid portions of the blood are drawn through the capillarics, sometimes causing them to crack, and the blood corpuscles to extravasate.

This view of the increased attraction between the blood and parenchyma, should it be only regarded as mere hypothesis, appears, at least, to be forced on us by a certain necessity. It must only be regarded as a short mode of expressing facts, in the same way that we make use of attraction and repulsion to express electrical phenomena, or of gravitation to explain a variety of physical facts. We should also remember that a theory in science can only be considered as correct or useful when it embraces every known fact. If it do this it serves as a principle or guide, which enables us to group together isolated phenomena without fatigue to the mind. We hope that the discussion we have entered into, though it necessarily consists of close reasoning, sufficiently exhibits that we have attained this end, and that the early phenomena of inflammation may be ascribed, 1*st*, to a vital contractility and relaxation of the capillaries, analogous to, if not identical with, spasm and paralysis in muscles; and 2*d*, to an increased attraction between the corpuscles of the blood and the surrounding parenchyma.

V. THE ESSENTIAL PHENOMENON OF INFLAMMATION.

Hitherto we have described a series of actions succeeding one another, commencing in contraction of the capillaries, and terminating in the escape of the blood or portions of it into the surrounding tissues. All these actions, however, are not equally important, nor do they all constitute inflammation. Up to a certain point this pathological state cannot be said to exist. The contraction and dilatation of the capillaries, the quick or slow movement of the blood, and even its stoppage, do not constitute inflammation. We frequently see these occur and pass off rapidly without causing any local or constitutional disturbance. Viewing the whole as a series of actions, we may readily understand that the process may stop short at any given point, and then return to its normal state. This, indeed, is the case. When that stage where the vessels are dilated and gorged with blood, and its movement is arrested or nearly so, has arrived, it is denominated congestion. This may terminate in the extravasation of blood, the effusion of the serum, or an anormal exudation of *liquor sanguinis*. But it is only when the latter takes place that we can state positively our conviction of the presence of inflammation. Hence it may be denominated the essential phenomenon of inflammation. Let us, however, examine more closely each of these occasional results of congestion.

Extravasation.—On examining the circulation in the tail of a living tadpole with a microscope, it will be seen, on the addition of acetic acid, and sometimes without, that, when the vessels are enlarged, the blood oscillating and about to stop, that many of the capillaries break in one or more spots. This often takes place in a stellate manner, and the blood escapes and collects in the form of a round button more or less large. The tail, if examined by a simple lens, will exhibit very minute red spots scattered here and there, and where these have apparently coalesced, the hemorrhagic spot will be more extended and irregular in form. In this case the congestion has terminated in hemorrhage. In man we see a similar evidence of a like extravasation in the bloody sputa of individuals attacked with pneumonia. In very acute inflammation of the brain also, we often find acute softening more or less connect-

ed with similar extravasations, which are then denominated capillary apoplexy. We have every reason to suppose, that in these latter cases, as well as in the tail of the tadpole, the extravasation arises from overdistension and rupture of the capillary vessels.

It can scarcely be conceived by any one who has carefully examined the blood-globules on the one hand, and the structure of the capillaries on the other, that the former can transude through the walls of the latter without rupture. Such an opinion may be considered as pure hypothesis, only supported by negative arguments. No one has ever seen such an occurrence. All positive observation indicates that, when transudation of blood really occurs, as in purpura, hemorrhagic diathesis, &c. the blood-globules are no longer in tact, but more or less broken down, whilst numerous granules are found in the fluid.

A very important question to determine is, how far such capillary hemorrhage is to be considered a proof of inflammation? We cannot suppose that the function of menstruation is a periodic inflammation, although undoubtedly the phenomena accompanying it are often nearly identical with those accompanying a genuine metritis. Local pains, accompanied by great constitutional disturbance, full pulse, hot skin, thirst, and all the symptoms of pyrexia, including relief from bleeding. Again, congestions recurring suddenly in the brain often produce capillary apoplexy and rapid death, the same as when a large vessel has been ruptured. But here again there is no evidence of inflammation, or of the existence of those symptoms which practical men have long attributed to cerebritis.*

Whilst, then, we know that capillary hemorrhage or extravasation of blood may occasionally accompany inflammation, we must deny that that circumstance alone is a proof of its existence.

Effusion.—That effusions of serum are induced by injuries and applications which excite inflammation cannot be doubted. The application of a blister is a ready means of producing this result, and, it may further be well observed, in vesicular diseases of the skin. Effusions no doubt are very common, but, in the great majority of instances, they arise from venous obstruction, altogether independent of inflammatory phenomena. Enlargements of the liver, pregnant uterus, abdominal tumours, &c. produce ascites from interrupting the venous circulation, and diseased heart or lungs occasion anasarca for a like reason. Here certainly the effusion is not inflammatory. In all such cases the fluid is clear, holds no fibrin in solution, and on being evacuated shows no disposition to coagulate. In inflammatory effusions, on the other hand, the fluid is more or less turbid, containing fibrin in solution, and, if allowed to stand, flocculi swim in it or sink to the bottom of the

* See Edinb. Med. and Surg. Journ. No. 157.

vessel. If we allow the vesicle in a blister to remain, we shall gradually see the fluid become more and more gelatinous and opaque. Even vesicular diseases of the skin induce exudation of blood plasma and a subsequent formation of pus, or produce scabs and crusts more or less thick, from the fibrin they contain drying on the surface. In short, in no case is it possible to procure pure serum, that is, serum unmixed with fibrin, as a result of inflammation. Hence, then, a great distinction between passive and active effusions, between venous and capillary dropsies.

Why it should happen that venous congestions are never accompanied by an exudation of blood-plasma whilst arterial congestions are, is a point that no one has yet endeavoured to explain. To me it appears certain that all inflammatory effusions occur through the capillary or intermediate vessels, and not in such vessels as may be properly called arteries or veins. The vein is a very compound structure, and when distended to the utmost only permits the more fluid portions of the blood to pass through. The capillary vessel, on the other hand, is a most simple structure and exceedingly delicate, so that when distended we may readily understand that it admits not only the serum but the more inspissated *liquor sanguinis* to pass through also. But it is scarcely possible to suppose that the mechanical difference in the tenuity of the filtrating membrane should constitute the only distinction. It is impossible to reconcile the phenomena without having recourse to some active vital power of attraction between the blood and parenchyma, as formerly explained ;—a power which, operating in the one case and not in the other, causes different constituents of the blood to become exuded. We are compelled, in all our considerations of the subject, to go back to this explanation, as to an ultimate fact.

Mere effusion, then, cannot in itself be considered as characteristic of inflammation. It may be the result of congestions non-inflammatory, or, if otherwise, passes more or less into exudation, which we shall now proceed to consider.

Exudation.—In every instance of undoubted inflammatory action an exudation of blood plasma occurs, which may be made visible. We have just alluded to this in connection with the subject of effusion,—a word which is often used synonymously with that of exudation. Thus we talk of pleuritic effusion to express an exudation of blood-plasma into the cavities of the pleura. In such situations where the *liquor sanguinis* is poured out into shut cavities nearly the same phenomena occur as when blood is drawn from the body. The fibrin coagulates and the serum is set free. The former then lines the serous membrane, and is denominated coagulable lymph, whilst the latter is called serous effusion. This

is identical with the serum effused in passive congestions, but, unlike it, was separated from the vessel in the form of *liquor sanguinis*, that is, holding fibrin in solution.

In parenchymatous tissues, however, as in the lungs, liver, brain, &c. the structure of the parts will not allow of this distinct separation. The *liquor sanguinis* exuded is, of course, at first fluid, and, in this state, insinuates itself amongst the elementary structure of the organs, filling up every minute space. When it coagulates, the tissues of the part affected are completely blocked up as if with cement. The blood-vessels, nerves, filaments, &c. are surrounded by a solid mass, in the same manner that the stones in a wall are surrounded by mortar. Hence increased hardness, density, and weight are communicated to such structures, constituting that state called hepatization, splenification, condensation, &c. Occasionally the *liquor sanguinis* seems to have the power of remaining fluid for a length of time without coagulating. Thus, Vogt relates a case where, on slicing the brain, a cavity the size of a walnut was cut across, from which a transparent fluid came out that afterwards coagulated. Nothing also is more common than to find effusions into the pleura or peritoneum, which, although fluid on first opening the body, afterwards become turbid and are seen to contain flocculi.

Exudation of blood-plasma, then, is essential to inflammation. We have seen that congestion may terminate in hemorrhage, or in effusion without constituting inflammation. But whenever it terminates in exudation of blood-plasma, that morbid process may be said to exist. We do not possess any other positive proof of the presence of inflammation than this, and by regarding exudation as the essential phenomenon, we at once give precision and exactitude to the term, and separate it pathologically from other morbid processes with which it has no affinity.

According to the ideas at present entertained respecting inflammation, exudation, instead of being considered as essential to that process, is rather regarded as one of its terminations. That is to say, pathologists conceive inflammation to consist of what we have called the early phenomena, which, according to them, are usually indicated by pain heat, redness, and swelling. By adopting this view, however, they are plunged into a crowd of inconsistencies. They are unable to separate congestion from inflammation, or to explain any one phenomenon of the process. In point of fact, they confound the congestion leading to inflammation with the inflammation itself, and ascribe those symptoms to the former which in reality belong to the latter.

These symptoms, indeed, of pain, heat, redness, and swelling have been made to play too important a part in our views concerning inflammation. They are only present when the lesion affects

the external surface, and are by no means applicable when it attacks many internal organs. I have seen cases of encephalitis where no pain or heat was manifested before death, and where no redness or swelling was to be afterwards discovered, although an undoubted inflammatory softening existed. Inflammation, also, may attack the lungs, liver, kidneys, &c., and yet one or more of these supposed cardinal symptoms be absent. Again, slight incisions, as those with a razor, are generally supposed to heal by means of inflammation, and so they do, but where is the pain, heat, redness, or swelling? In short, the symptoms of phlegmon, which so frequently come under the notice of surgeons, have been by them too generally applied to all inflammations. An analysis of these symptoms, also, will show that, whilst some depend upon the previous congestion, others are attributable to the exudation which follows it. Thus, the heat and redness are caused by the former, whilst the pain and swelling usually result from the latter. The presence of these symptoms, therefore, cannot be considered as essential to inflammation, whereas this state can never exist, however slight or however severe, without exudation of blood-plasma.

Other pathologists have felt the difficulties which attend the considering exudation as a result rather than as the essential phenomenon of inflammation. Thus Dr Alison observes, "in order to give the requisite precision to the general notion of inflammation as a local change of the condition of any part of the body, it seems only necessary to include in it, besides the pain, swelling, heat and redness, the tendency always observed, even when the changes in question are of short duration, to effusion from the blood-vessels of some new products; speedily assuming, in most instances, the form either of coagulable lymph or of purulent matter.* If, instead of "tendency to," we read *existence of*, effusion, the principle laid down is certainly correct. Yet only to exhibit the inconsistencies which attend the present method of regarding inflammation, let us observe what is stated by Dr Symonds in the same volume, and in the article preceding the one just cited. He says, when speaking of purulent secretion, "purulent matter may be found in masses of various dimensions in the substance of the lungs, the liver, and other organs, notwithstanding there may have been no symptoms of inflammation in these parts during life, &c." "We cannot doubt that this deposition" (that is purulent matter) "may exist under circumstances which forbid our supposing that the organ in which it is found had been affected with inflammation, &c."† Here, then, the very circumstance which Dr Alison has considered necessary to give precision to the term inflammation, is acknowledged by Dr Symonds as capable of existing without that process. Again, whilst some modern surgeons

* Lib. of Med. Vol. i, p. 53. † Ib. p. 24.

are of opinion that it is impossible for the smallest wound to unite without inflammation, (Astley Cooper,) others contend that it is opposed to adhesion or regeneration of parts, (Macartney.) These and various other discrepancies are at once removed by considering an increased exudation as the essential phenomenon of inflammation.

When the *liquor sanguinis* is exuded, it generally coagulates and constitutes a foreign body in the texture of the parts affected, which it becomes the object of nature either to remove from the system, or so to modify that its presence may be rendered conducive to the wants of the economy. For this purpose it undergoes certain vital changes, which differ in particular situations, and under certain circumstances. It serves as a blastema in which new organisms, that is, nucleated cells, are originated and developed. By means of the new growths thus produced, the exuded blood plasma becomes converted into a variety of products, which are ultimately reabsorbed into the circulation, discharged from the body, or changed into permanent tissues. Occasionally, however, the exuded blood plasma undergoes no such changes, it seems to lose its vitality, and is rendered incapable of either becoming absorbed, of passing into nucleated cells, or permanent formations. Under these circumstances, the blood plasma effused, and the textures loaded with it, lose their vitality and die. All these various changes, which we shall next proceed to consider, may be denominated, in the ordinary language of pathologists, the terminations of inflammation.

VI. TERMINATIONS OR RESULTS OF INFAMMATION.

The expression, termination of inflammation, which has been sanctioned by general usage, is here used to signify the changes which the *liquor sanguinis** undergoes after having been exuded through the blood-vessels. We have described the early phenomena, and the essential phenomenon of inflammation, and these changes constitute the resulting or subsequent phenomena.

What have hitherto been considered as the terminations of inflammation, viz. adhesion, softening, induration, suppuration, granulation, ulceration, gangrene, &c., modern pathology has shown to be in themselves highly complicated processes. John Hunter was of opinion that these various results were explained by supposing the inflammation to undergo certain modifications, or that it terminated differently according to certain tendencies which it possessed; hence the terms adhesive, suppurative, ulcerative and gangrenous inflammation. According to the view, however, which we have endeavoured to establish, viz. that inflammation essentially consists in an increased exudation of blood-plasma, it follows that this process in every tissue and under all circumstances is the same. The exudation having once taken place, any further changes we may observe in it will depend upon the amount or rapidity with which it is poured out, the tissue in which it occurs, its chemical and vital proportions, and the accidental circumstances which modify or destroy growth both in the vegetable and animal world.

Whenever the exudation of blood-plasma poured out coagu-

* It is perhaps necessary to say that we employ the terms *liquor sanguinis* and blood-plasma as synonymous with each other, understanding by them the fluid portion of the blood composed of fibrin dissolved in serum.

lates, it can only be removed from or assimilated to the economy by one of two results, viz. by death, or by passing into organization. When it does not coagulate, which is an occurrence of great rarity, it may again pass into the vessels by endosmosis, and in this way the parts return to a normal state. Resolution, however, as at present understood, is a very compound process. It is used to express the disappearance of the inflammation without its producing any external lesion. In this manner resolution may follow hæmorrhage, softening, or suppuration, and great difficulties impede our attempts to ascertain with exactitude how, under these circumstances, the exuded and organized blood-plasma is absorbed. For this reason, therefore, we shall discuss this portion of our subject in the following order: 1st, the termination of inflammation in death of the part; 2d, the termination in organization; and 3d, the termination in resolution.

1. The termination of inflammation in death of the part.

This may be either acute or chronic, the former constituting mortification or moist gangrene, the latter ulceration.

Mortification.—Occasionally a very large amount of blood-plasma is thrown out, constituting a violent inflammation; a greater or less number of capillaries are also ruptured, and blood corpuscles are more or less mixed up with the *liquor sanguinis* exuded. The exudation thus formed compresses the part so as to obstruct the blood-vessels, and prevent the continuance of any circulation in it. Under these circumstances, instead of forming a blastema for the production of new organisms, it undergoes chemical changes which induce in it decomposition, and the part is said to be mortified, or to be affected with moist gangrene. This change commences first in the blood extravasated, which becomes of a purple colour, more or less deep; the corpuscles break down and become disintegrated, their hematozine dissolves and colours the serum, and should the exudation have coagulated, it forms brown, rust-coloured, purple, or blackish masses. An acid matter is now formed, which, acting on the neighbouring tissues, produces fœtid gases, that are abundantly given off from the affected part. Sulphuretted hydrogen is evolved, which causes the blackish sloughs usually observed in such cases, and discolours silver probes and the preparations of lead. After a time, the elementary tissues surrounding or involved in the exudation become more or less affected. The transverse striæ in the fasciculi of voluntary muscles become first pale, and are then obliterated. Cellular tissue, fat, and other soft substances, lose their connection and fall into an undefined granular mass. The

tendons and fibrous tissue retain their characteristic structure for a long time after the other soft parts have been reduced to a softened pulp. The bones resist the action longest, but at length become rough, soft, and, commencing externally, are more and more broken down, and reduced to the same pulpy consistence and granular structure as the surrounding parts.

As the tissues thus become broken down and fluid, they are discharged from the system in the form of an ichorous matter, which, examined microscopically, presents numerous granules, imperfect or broken down cells, blood corpuscles, and fragments of filamentous tissue or the other structures involved. If the morbid action be seated in the subcutaneous tissue, the skin soon becomes involved, and an opening is formed, which rapidly increases and gives vent to the discharge. In a similar manner gangrene of internal organs, by destroying the intermediate parts, at length enables the discharge to reach the surface, or to find its way into the excretory passages, such as the bronchi, the intestinal canal, the *meatus auditorius*, &c. In this manner life may be endangered by the destruction of organs important to life, by the exhaustion occasioned by the discharge, and sometimes by the absorption of the ichorous matter, which, by entering into the circulation, acts as a poison to the economy.

It may be asked whether inflammation and gangrene are similar processes,—whether the latter is only a greater intensity of the former,—or whether, when gangrene follows inflammation, it is dependent on other circumstances, such as a peculiar state of the atmosphere favouring the decomposition of the exudation poured out. In order to answer any of these questions we must distinguish between mortification arising from a variety of circumstances, and an inflammatory gangrene properly so called, the which is undoubtedly the rarest of all the terminations of inflammation. We frequently see mortification produced by the application of chemical or mechanical agents, which directly destroy the tissues. It also arises from severe and complicated injuries, in which arteries leading to the portions of structure affected have been divided or crushed. In old persons it follows obstruction in the blood-vessels, or is dependent on circumstances not yet ascertained. In none of these cases is it caused by inflammation. But when stasis of the capillaries is produced to a considerable extent, followed by the exudation of a large quantity of blood-plasma, which, instead of passing into organization, undergoes the changes previously described, then an inflammatory mortification, properly so called, is produced. We see this take place after burns, a long exposure to frost, and in certain cases of erysipelas. Here the amount of exudation is considerable, the pressure caused by it extreme, the obstruction to the circulation in the neighbouring

parts correspondingly great, and these, as well as the exudation itself, die. In this sense, therefore, it may be said to depend on the severity of the inflammation. This, however, is not the case in the sense of those who consider the adhesive, suppurative, and gangrenous inflammations as different stages of one process. Suppuration, as we shall afterwards see, has no connection with adhesion, nor is it in any way related to mortification. It is a primary alteration of the exudation. Its vitality is lost, and, instead of passing into organization, as we shall hereafter describe it, it at once becomes subject to the chemical laws of dead matter.

On the other hand, mortification occasionally arises under circumstances in no way connected with the amount of the exudation, or the rapidity with which it is thrown out. During the summer of 1836, I watched with great care the progress of a sloughing gangrene, prevalent not only in the Infirmary of Edinburgh, but through the city generally. All kinds of sores and wounds were affected by it, even those of a specific nature, such as chancres. Neither youth or age was exempted from it. It affected not only those who were debilitated from disease, by intemperance or bad diet, but those also in the most robust health. Thus a servant girl, aged 16, who had never suffered from illness, and of a robust constitution, fell down upon some glass bottles, and slightly cut her left thumb. A week after, she entered the Infirmary with an ulcer the size of a shilling, filled with a brownish-black slough, and discharging a fœtid and sanguineous fluid. In this, as well as other cases which occurred, it became impossible to attribute the gangrene either to the violence of the injury, the amount of exudation, a state of cachexia, or indeed to any circumstances connected with the individual. It could not arise from contagion, as it existed in different parts of the city, was not confined to the Infirmary, and the system of dressing wounds there precludes the possibility of this explanation. We are, therefore, compelled to ascribe the cause to something without. Most writers have noticed the connection between a certain state of the atmosphere and the prevalence of hospital gangrene.* Its frequent occurrence in summer, that is, at a period of the year when increased temperature favours the decomposition of animal matter, and the good effects which result from change of air, when every kind of treatment fails, still farther point out its origin from changes occurring in the atmosphere.

Ulceration.—The process of ulceration is somewhat similar to that of mortification, only it is more chronic, and the exudation, instead of undergoing decomposition, only exhibits an indisposition to pass into organization. In this case the exudation is

* See Boggie, Thomson, Hennen, and Blackadder on Hospital Gangrene.

poured out slowly, it coagulates and presses upon the surrounding parts, more or less obstructing the flow of blood to them, and acts as a foreign body. By means of the continued pressure, the circulation is obstructed, and death of the portion affected results. Sometimes this is imprisoned in fresh exudation, as ulceration extends, and the whole at length becomes disintegrated. All this time the exudation exhibits little of that tendency so conspicuous in healthy persons to undergo changes in itself, and when examined microscopically is found to consist principally of very minute granules, varying in size from $\frac{1}{12.000}$ to the $\frac{1}{500}$th of a millimeter in diameter. These are occasionally mixed with irregularly formed cells, usually more or less angular, containing one or more granules. The cells are more numerous in proportion to the stage of the ulceration, and the healthy powers of the constitution. These different granules and imperfect cells, with the structures they involve, at length become broken down, and separated from each other, constituting a semi-fluid mass, which has a tendency to point where it can most readily be discharged, that is, towards the surface of the skin or mucous membranes. Here, on account of the less degree of resistance offered, the continued pressure and disintegration of tissue first causes an aperture to be formed. Another portion of solid exudation is now broken down, with the tissues involved in it, and in this way the opening is enlarged. If the morbid process continue, a fresh exudation is slowly poured out below the already coagulated blood-plasma, which supplies the loss thrown off in the form of discharge, and thus chronic ulcers may be continued indefinitely. The whole of this process may be well observed in scrofulous and syphilitic ulcers, or in the callous sores of the leg in weavers and others of a cachectic constitution. Indeed the general powers of the constitution are almost always in such cases enfeebled, and hence the indisposition of the exudation to be transformed into organized cells.

Ulcers produced by direct pressure are occasioned in a similar manner; only in such cases the pressure is not derived in the first instance from the solid exudation poured out. Thus, in stumps not sufficiently covered by soft parts, in places long pressed upon by lying, or by the growth of tumours, the vitality of the part is slowly destroyed. At the same time an exudation is poured out from the neighbouring vessels, which becomes broken up, and assists in disintegrating the textures whose vitality is destroyed. The finely molecular particles are thus absorbed, whilst the grosser portions are thrown off in the form of discharge.

All ulcerated surfaces are covered with a fluid, which varies in character according to the nature of the sore. Healthy granulations are covered with laudable purulent matter, and the corpuscles present their normal character. In chronic scrofulous and syphilitic sores the corpuscles are generally of an irregular form,

constituting what has been denominated anormal purulent matter. Not unfrequently the ulcer is covered with an unhealthy-looking discharge, either of a thin dirty yellowish tint, or more or less sanguinolent and fœtid. In the latter case the discharge has received the name of sanies, and is similar in character and constitution to that observed in the fluid accompanying inflammatory mortification. That is to say, there are traces of imperfect cell formation, mixed with numerous molecules, and the shreds or debris of the structures involved.

Ulceration has by most writers since the time of Hunter been regarded as the result of a peculiar operation, which he denominated ulcerative absorption. No doubt the process, such as we have described it, is peculiarly favourable to the production of a fluid containing molecules so minute that they may readily permeate the neighbouring vessels by endosmosis. On this subject we shall dwell more at length under the head of resolution or absorption. In the mean time it must not be overlooked that much of the loss of substance observed in inflammation, especially of the more consistent and tough structures, after having been more or less broken up, are thrown off from the surface in the form of discharge. This is proved by direct observation. In either case all such parts first loose their vitality, from the pressure to which they are subjected, and then being broken down, the fluid and finer parts may be absorbed, whilst the coarser are thrown off from the surface.

The treatment in all such cases must evidently be to remove the pressure which destroys the vitality of the part. When mechanical causes exist the mode of doing this becomes obvious. But when, as in the case of constitutional ulcers, the pressure is derived from an exudation which has no tendency to organization, then our efforts must be directed, 1*st*, to cure the constitutional disease, and thereby change the morbid condition of the blood-plasma ; 2*dly*, to facilitate the disintegration and discharge of the coagulated exudation by means of alkaline lotions ; or, 3*dly*, to favour its passage into organization by fomentations, poultices, &c.

When loss of substance occurs by accident, or from wounds in a healthy constitution, there is no process of ulceration properly speaking. Nature immediately commences to repair the injury, and completes this by the process of granulation and cicatrization. These results will more properly be considered under our next head, namely,

2. The termination of inflammation in organization.

From what has previously been said when speaking of the cellular theory of nutrition, it follows that organization consists in the

formation and development of nucleated cells. Thus, purulent matter is not to be considered as a secretion from the blood, to be like urine excreted from the body, but as a fluid in which, like the blood itself, numerous corpuscles or organisms float. These corpuscles have a distinct structure, they each possess vital power independent of each other, and pass through a definite origin, growth, and decay, like all other living beings. It is in this sense, therefore, that we employ the term organization, without reference to the existence of vascularity, which for so long has been considered the great characteristic of new vital formations.

In the great majority of cases, when inflammation has occurred, the blood-plasma exuded seems as a blastema, in which numerous cells are produced and nourished. These cells are of various kinds, and possess different powers of development. Some complete their growth when the cell-wall has reached its utmost size. In others, numerous granules are formed; whilst a third class undergo a gradual metamorphosis into more compound tissues. These either resemble those structures which have been inflamed, unite surfaces which have undergone a breach of continuity, and serve as a substitute for any part which has been removed, or, in particular states of the constitution, they form the various kinds of morbid depositions and growths, either simple or malignant. The circumstances which induce or influence these different results, will be treated of in a separate section; in the meantime, it may be said that the exudation becomes organized as follows:—1*st*, By the formation of (*plastic*) corpuscles and primitive filaments, constituting lymph; 2*d*, By the formation and disintegration of (*exudation*) corpuscles, producing softening; 3*d*, By the formation of (*pus*) corpuscles, occasioning suppuration; and, 4*th*, By the formation of corpuscles which pass into filamentous, fibrous, osseous, muscular, or other tissues.* One or more of these processes, as we shall afterwards see, may be combined together; but it will be necessary for us, in the first instance, to treat of each separately.

1. *Of the transformation of the exudation into primitive filaments and corpuscles, constituting lymph, as seen on the surface of serous membranes.*—Here the blood-plasma exuded coagulates, the fibrinous portions solidify and attach themselves to the membrane, whilst the serum is set free and occupies the intervening space of the shut cavity. In this case, when the inflam-

* To complete the history of the exudation, it would be necessary to add, 5*th*, The formation of granules and imperfect cells, constituting tubercle; and, 6*th*, The formation of variously formed corpuscles and filaments, which, in the aggregate, constitute tumours, either homologous or heterologous. We shall treat of these on another occasion.

mation is acute, the process is identical with the coagulation of the blood without the presence of blood corpuscles. The coagulated portion is now usually termed lymph, and presents different appearances according to the rapidity with which it is thrown out, and the extent of the membrane affected.

In very acute cases of pleuritis, which have proved rapidly fatal, I have repeatedly observed the following appearances. On carefully elevating the sternum, care having been taken not to disturb the body for some hours, the pleural cavity on the side affected has been found full of apparently a clear fluid of a yellowish or greenish tint. On emptying this by means of a small shallow cup, the first portions removed have been perfectly clear and transparent. On continuing to empty out the fluid, it has been observed that the deeper we descend the more turbid it becomes, until at length nothing but a semifluid mass is removed. It will frequently be found that large portions of this mass, although tolerably consistent, are semitransparent, resembling a light-coloured calf's-foot jelly, whilst other portions present the usual opaque appearance. Sometimes, when the body has been undisturbed for twenty-four hours, the whole exudation is separated into two distinct portions. The upper, fluid and perfectly transparent, whilst the lower is composed of a pultaceous mass, resembling a bread-and-water or oat-meal poultice. In all such cases, the fibrinous portions, from their superior specific gravity, have sunk to the bottom, whilst the supernatant serum remains clear. The semitransparent lymph is the portion most recently exuded, in which very few of the plastic corpuscles, afterwards to be described, have been developed.

When the progress of the exudation is less rapid, the lymph assumes a more consistent appearance, and forms flocculi of different sizes, or a distinct lining, varying in thickness from half a line to an inch, over the part inflamed. Occasionally it is smooth, but sometimes it presents a honey-combed appearance, or hangs in loose flakes of a dendritic appearance in the serum. The surface is generally smooth on lymph effused in the subarachnoid cavity. It is frequently honey-combed on the pericardium, which is owing to the repeated closing and separation of opposed surfaces. It is often dendritic or stalactitic on the pleura and peritoneum, and is probably owing to one drop of plasma being exuded on a portion which has previously coagulated, as Vogel suggested, in the same manner that stalactites of carbonate of lime are formed in a cavern. Serous membranes, when inflamed, frequently resemble mucous surfaces, from the villous appearance the effused lymph assumes; and, in point of fact, it performs the functions of a mucous membrane for a time, and is very active in absorbing the serum, which, if the inflammation ceases, gradually

disappears. This villous aspect of lymph is very commonly seen on the pericardium and peritoneum. Occasionally also it assumes a lamellar arrangement, attributable probably to repeated exudations of blood-plasma at different times. This may be frequently observed in the pleura, and layer after layer readily dissected off.

When the inflammation has been less acute, or is of longer standing, we find, after death, that the coagulated blood-plasma or lymph has become more consistent. It never assumes a fibrous appearance, often extending between opposed serous surfaces in the form of bands, which have considerable tenacity and strength. These bands have a great disposition to contract, and ultimately become shorter and shorter, and assist in forming a dense substance, which at length firmly unites together the serous surfaces. This uniting substance becomes more and more dense, and not unfrequently resembles ligament in toughness and general aspect. In this form it may frequently be seen in phthisical cases, uniting together the lobes of the lung. Occasionally it assumes even a cartilaginous hardness, resembling the fibro-cartilage of the intervertebral surface. In this state it may frequently be seen on the spleen, and I have seen it thus half an inch thick, intimately uniting the lungs to the ribs. Lastly, when it has been very slowly developed, it produces white indurated patches, of a glistening cartilaginous appearance, varying in extent, the surface of which has assumed the character of a serous membrane, and in no way interferes with the movements of neighbouring organs. Such patches are exceedingly common on the surface of parenchymatous organs, as the heart, liver, spleen, and kidneys.

On examining the minute structure of lymph, in the various forms and stages now described, we find the following: At the very earliest period, when it presents the gelatinous semitransparent appearance, we find it to be made up of a minute filamentous structure, first described and figured by Gruby,* and subsequently by Gulliver† and Vogel.‡ It is identical with the structure observed in the colourless clots of blood so frequently found in the heart, and with the buffy coat of inflamed blood, as first seen to form under the microscope by Addison.§ The filaments appear to be made up of exceedingly minute molecules, arranged in rows, similar to what is seen in mucus on the addition of acetic acid, (Plate VII. Fig. 2.) When recent lymph becomes opaque, or, as it is generally observed, it consists of two elements; 1*st*, The same filaments just alluded to, which, however, may now be observed to be larger in size, more distinct, and less molecular; 2*d*, A quan-

* Obs. Microscopicæ. † Gerber's Anatomy.
‡ Icones Histologiæ Pathologicæ.
§ Prov. Med. and Surg. Associat. Trans. Vol. xi.

tity of corpuscles, which are entangled among the filaments, although easily separated from them by washing, or by pressure between glasses, (Fig. 3.) These corpuscles, for the most part, are from $\frac{1}{100}$ to $\frac{1}{75}$ of a millimetre in diameter, formed of a delicate wall, containing granules from $\frac{1}{1000}$ to $\frac{1}{500}$ of a millimetre in diameter, which vary in number from 3 to 12. They are not perfectly round, but somewhat irregular in form. They differ widely from purulent matter, for which they are usually mistaken, not only in their general appearance, (which will at once be recognised by the experienced observer,) but in the effect produced on them by reagents. Thus, on the addition of acetic acid, they frequently undergo no change, or become more transparent, and at others the wall contracts, and the edge becomes thicker and more irregular. It is dissolved in ether and caustic potash, and not affected by water. These corpuscles have been described and figured by Gruby* and Vogel,† as those of purulent matter, by Valentin‡ and Gulliver§ they have been denominated exudation corpuscles. We shall see, however, that both these terms have been applied to other structures. With a view of distinguishing them, therefore, from these, I denominate them *plastic corpuscles,* on account of their constituting the characteristic structure of plastic lymph.

All specimens of recently exuded lymph on the surface of serous membranes will be found to be made up of the filaments and corpuscles now described. The former are most abundant in those portions which adhere together, and the latter in the gelatinous, pulpy, and fluid portions. The corpuscles found in all recent inflammatory effusions occurring in the pleura, pericardium, and peritoneum, will be found very rarely to contain purulent matter, but most commonly an innumerable number of plastic corpuscles, occasionally mixed with a few filaments more or less broken up.||

At a later period, when most of the fluid has been absorbed, and the lymph is more consistent, it will not unfrequently be observed, that cells exist in it which are undergoing development into fibres, as noticed by Henle¶ and Engel,** (Figs. 5, 6, 7.) Mixed with these will be observed, filaments in every respect similar to those observed in the ordinary cellular tissue of descriptive anatomists. In more chronic cases, where the exudation resembles bands, the structure is identical with that of filamentous tissue, and when it firmly unites opposite surfaces, the minute fibres are arranged close together, as is observed in the fibrous or ligamentous

* Obs. Microscop. Fig. 64.

† Tab. Histologiæ Path. Pl. 3, fig 5.

‡ Repertorium, 1838, p. 273.

§ Phil. Mag. Vol. xxi. p. 171.

|| See a valuable paper on this subject, by Mr Gulliver, Phil. Mag. Vol. xxi. p. 241.

¶ Bericht. p. 171.

** Oesterr. Med. Wochen. 1843, No 3.

tissues in general. The white, glistening, and indurated patches so frequently seen on the spleen and heart, do not present a cellular structure, but are densely fibrous, and analogous to fibro-cartilage.

Such are the ordinary appearances and minute structures which the exudation presents when poured upon the surface of serous membranes. The filaments in recent lymph are evidently the result of deposition, which is produced as the fibrin of the *liquor sanguinis* coagulates. These are primary. But are the filaments in old lymph the same, only increased in size, or are they the result of cellular development, that is to say, secondary? From the occasional appearance of cells undergoing the transformation into fibres, as originally described by Schwann, this seems probable. At least it is certain that secondary filaments are developed amongst the primary, which communicate to the tissue increased strength and elasticity, and bestow upon it that highly contractile property so characteristic of effused lymph. After a time, we can observe no traces of the primary filaments, only fibrous tissue remains. Whether they are dissolved, or in what manner they disappear, I have not yet been enabled to determine.

In this, as in all other kinds of blastema, we find corpuscles produced. We have shown that they are not those of purulent matter, and have characters which distinguish them from other cell-formations. It may be asked, how are they formed, and what is their ultimate destination? On these points our knowledge is in a very unsatisfactory state. They only contain granules, without any distinct nucleus, and hitherto we have been unable to trace their origin. Again, whether their life terminates with the degree of development which has been described, and they are again dissolved; whether they are the nuclei of the fibres afterwards produced, or whether they are ever transformed into purulent matter, are points equally unknown. Some facts, to which I shall subsequently allude, indicate that corpuscles analogous to purulent matter are occasionally produced even on serous surfaces. It may also be asked, are the cells which undergo transformation into fibres a subsequent production? Do they owe their existence to an after exudation from new vessels which have been formed? All these queries can only be solved by further investigations. It is at least certain, that the changes observed in chronic lymph, the transformation into filamentous and fibrous tissue, is attributable to the development which cells undergo, according to the well-known law of cytogenesis, as brought forward by Schleiden and Schwann.

2. *Of the transformation of the exudation into granules, masses, and cells, and the occurrence thereby of inflammatory softening, as seen in the substance of parenchymatous organs.*—In parenchymatous organs, such as the brain and lungs, we find

that the exudation of *liquor sanguinis* is followed by a very different appearance from what characterizes it when poured out on the surface of serous membranes. Here, instead of being spread over a surface and coagulating in a continuous sheet, it is insinuated among the elementary structures of the organ, into every minute space, imprisoning them, so to speak, in a cement which afterwards solidifies. At the same time, a great portion of the serum is rapidly absorbed. In the generality of cases, a quantity of blood is also extravasated with the plasma, more especially in the lungs, where this lesion is denominated red hepatization. With respect to this organ, indeed, it would seem at first sight to be hardened by this change, and, in point of fact, it becomes more dense, and readily sinks in water. Reflection, however, will show that the term hardening here is merely comparative. A lung so affected is undoubtedly harder and heavier than it was in its previously spongy, light, and healthy state, on account of the displacement of air by the solidified exudation. But if the finger be thrust into a healthy, and then into a hepatized lung, it will be found that, whilst the former offers considerable resistance, the latter is friable and readily breaks down, proving that, in point of fact, an inflammatory softening of the tissue has taken place. In the brain, liver, or any other organ naturally dense, the softening from inflammation is rendered at once apparent, and, when increased, is found to be pultaceous and even diffluent. In the brain they assume various colours, and are called the red, fawn, yellow, and white softenings, which depend upon the amount and condition of the blood effused, and the greater or less admixture of serum. In the lungs the softening may be red or gray, but this is dependent upon the formation of different organisms in the part affected.

The minute structure of the exudation in parenchymatous organs varies according to its amount and the rapidity with which it is poured out. The exudation, instead of coagulating in the form of filaments, as when lymph is produced, consists of minute granules, varying from a size scarcely measurable up to the $\frac{1}{500}$th of a millimetre in diameter. This granular formation may be seen coating the vessels, in layers more or less thick according to the quantity exuded, (Figs. 9, 10, 11.) Sometimes only a few are scattered over the external surface of the vessel, (Fig. 10,) at others it exists in dense masses, filling up all the interstices between the vessels, (Fig. 11.) If examined when recently exuded, nothing but a finely granular and dense mass can be observed. At a little later period, however, we may see in the exudation round bodies, perfectly transparent, with defined edges, varying in size from the $\frac{1}{200}$th to $\frac{1}{100}$th of a millimetre in diameter. (Fig. 9.) Still later we see similar colourless bodies surrounded by a cell-wall, presenting all the characters of a nucleated corpuscle, containing several minute granules, (Fig. 10, *a*.) At the same time

other cells are apparent, whose walls are completely distended with those granules, and the transparent body (nucleus) is obscured, (Fig. 11, *a.*) We now find that the exudation is broken up, the granules are separated from each other, although masses more or less large adhere together, and may be distinguished from the nucleated cells, by their irregular form and edge, as well as by the absence of a cell-wall, (Fig. 12, *a.*)

In this state we find the exudation presenting three kinds of objects, which I have denominated exudation granules, masses, and cells. The latter, called exudation cells, to distinguish them from the plastic corpuscle on the one hand, and pus corpuscles on the other. They are round or oval in form, their long diameter for the most part varying in size from the $\frac{1}{75}$th to the $\frac{1}{50}$th of a millimetre in diameter, although I have frequently seen them much larger, (Fig. 12.) They are frequently of a brownish or blackish tinge, and when full of granules, are so dense as to obstruct the transmission of light. The addition of water causes no change in these bodies. Acetic acid most frequently produces no change, but at others, the cell-wall is rendered somewhat transparent by it. They are soluble in solutions of potash and ammonia, in the former more rapidly than in the latter. Sulphuric ether dissolves them immediately.

On gradually pressing the perfect corpuscle, by means of a compressor, large drops, like those of oil, may sometimes be made to appear within the cell-wall, or to exude through it, and this subsequently becomes more or less collapsed. By means of friction the cell-wall may be ruptured and its contents dispersed. The nucleus under such circumstances will often be found to be very persistent.

All these appearances are best observed in the brain, on account of the facility with which the morbid products may be distinguished from the healthy structure. The same changes, however, may be seen in the lungs, although, from the very compound structure of that organ, they are not so easily determined. In the red hepatization numerous exudation granules, masses, and cells may be seen infiltrated into the pulmonary tissue, and floating loose, mixed with epithelial cells from the bronchi. In the gray hepatization, other corpuscles may be seen. These resemble in size and structure plastic corpuscles, only the cell-wall is rendered transparent by acetic acid, whilst the granules are unchanged, (Fig. 4.)

The formation of exudation granules, masses, and corpuscles, according to my observations, take place in the following manner. The exudation first coagulates in minute granules—the colourless and larger bodies soon after seen among these are nuclei, from which a cell-wall arises. During or subsequent to its growth, granules are formed between the nucleus and cell-wall.

These become more and more numerous until at length the nucleus is obscured, and the whole cell appears full of and distended with granules. In this state it assumes a brownish or black appearance; in the latter case it is opaque. The idea of Gluge, that these bodies are formed within the vessels, is evidently incorrect. Some have denied the existence of a cell-wall, but they must have mistaken the broken or disintegrated masses for the corpuscles. Henle has described them as two distinct formations. The first he calls the inflammation globule after Gluge,* the second he denominates after Vogel, granular cells.† The former he considers the primary formation, whilst Vogel considers them secondary, and the result of the latter breaking up. My own observations have led me to the conclusion, that the exudation masses which possess no cell-wall are nothing but portions of the coagulated exudation which split up and peel off from the vessels. In point of fact I have seen this take place under the microscope. The cells, on the other hand, are formed according to the general law of cytogenesis, as previously described. When these are distended with granules, the structure appears to have reached its farthest stage of development, the cell-wall now bursts or is dissolved, and its contents escape. The growth and subsequent disintegration of these corpuscles, proceeding simultaneously in the exuded mass, cause the whole to be broken up, and to become soft, pultaceous and even diffluent. In this manner inflammatory softening is produced, which may easily be distinguished from the softening of maceration or putridity by the presence of the exudation cells, masses or granules.

Exudation corpuscles and masses, such as they have now been described, are seen in greater or less numbers in the milk first secreted after parturition. They were first described by Mandl as granular bodies of the colostrum. From numerous observations made on the milk of nurses in 1841, assisted by Dr Potts, now of Jersey, I am satisfied that these granular bodies are exudation corpuscles, arising from congestion, followed by exudation into the mammary gland, (Fig. 13.)

3. *On the transformation of the exudation into corpuscles constituting suppuration, as observed in cellular tissue, or on mucous and granulating surfaces.*—The formation and collection of the fluid long known as purulent matter, is most commonly found on the surface of mucous membranes and granulating sores, and in the cellular tissue beneath the skin, or entering into the different dense organs of the body. The purulent matter formed in a phlegmonous abscess, or that discharged from a healthy granulating sore, must be considered as the type

* Bericht, p. 182. † Bericht, p. 19.

of this formation. Here we find it to be an opaque, unctuous, straw-coloured or slightly greenish fluid. If allowed to remain at rest, it separates in a few hours into two parts,—a thick yellow deposit, and a clear yellowish supernatant liquid, (*liquor puris.*) In this state it may be kept for months in a closed bottle without undergoing any marked change.

When collected together in any organ or tissue, so as to constitute an abscess, we find it preceded by well-marked pain, heat, redness and swelling. At first we find the part indurated, which is owing to the presence of exudation from the vessels. After a time this becomes softer and softer, until at length fluctuation is felt, and suppuration said to be established.

Mr John Hunter, speaking of spontaneous suppuration, says, "If it is in the cellular membrane that this disposition takes place, or in the investing membranes of circumscribed cavities, their vessels now begin to alter their disposition and mode of action, and continue changing till they gradually form themselves to that state which fits them to form purulent matter; so that the effect or discharge is gradually changing from coagulating lymph to purulent matter; hence we commonly find in abscesses, both coagulating lymph and purulent matter, and the earlier they are opened the greater is the proportion of the former. This gave rise to the common idea and expression, "that the matter is not concocted;" or that "the abscess is not yet ripe." The real meaning of which is, "the abscess is not yet arrived at the true suppurative state."* The facts so accurately detailed by Hunter we are now enabled to explain more correctly. The transformation of the exuded lymph into purulent matter does not depend upon any change in the vessels, but upon a process of growth taking place in the lymph or exudation itself, by means of which numerous corpuscles are produced. The expression "the abscess is not yet ripe" is singularly correct when applied at a period when the pus corpuscles have not reached maturity.

The corpuscles in laudable purulent matter are perfectly globular in form, and vary in size from the $\frac{1}{100}$th to $\frac{1}{80}$th of a millimetre in diameter. Their surface is finely granulated. They have a regular well-defined edge, float in the *liquor puris*, and roll freely upon each other. On the addition of water, they become much increased in size, their finely granular surface disappears, and they become more transparent. Weak acetic acid partially, and the strong acid completely, dissolves the cell wall, and brings into view the nucleus, which generally assumes the appearance of two or three granules close together, each with a central shadowed spot They are generally about the $\frac{1}{400}$th of a millimetre in diameter.

* On the suppurative inflammation.

Occasionally four or even five granules may be observed. Alkalies and ether entirely dissolve them.* (Fig. 15, *a.*)

On examining the masses of lymph occasionally evacuated with purulent matter from an abscess, not yet ripe, they will be found to consist of a finely granular matter; occasionally larger granules may be observed in them sometimes arranged in twos and threes, similar to the nuclei observed in the pus corpuscle. Vogel has figured these nuclei in the exuded mass surrounded by a transparent cell wall.

With respect to the manner in which pus corpuscles are formed, the observations of Vogel, Henle, Lechmann, and Messerschmidt, agree in supporting the view that they arise in the coagulated exudation as a blastema. The central granules constitute a nucleus from which the cell wall arises until the perfect corpuscle is produced. This process going forward in a vast number of such organisms, break up the solid fibrinous mass, which becomes fluid, and at length converted into purulent matter. In the fluid produced by blisters, and in the early stage of pustules formed by frictions with tartar emetic ointment, molecules and delicate corpuscles, varying in size and in all stages of development, may be observed. On the addition of acetic acid their nuclei become beautifully apparent. Pus corpuscles generally evacuate themselves externally, but occasionally, as we shall afterwards see, they are broken down and absorbed.

According to Vogel, purulent matter may be formed both from exudation rendered solid and from the fluid blood-plasma before coagulation. It is formed in the latter way principally on mucous or granulating surfaces, as well as in fistulæ and on the lining membrane of abscesses, when the original collection of matter has been evacuated; in both cases, however, the process of formation is the same, only the blastema being more consistent in one than in the other. The idea put forth by Vogel, that the pus corpuscle is a species of epithelium cell may be considered correct, if by the latter term he understands any kind of cellular structure thrown off from the surface of membranes; but if it be meant that the normal epithelium cell ever becomes converted into a pus corpuscle, the opinion is opposed to observation, and inconsistent with the large granulations of the latter produced. Neither have I ever seen any grounds for supposing with Gerber that they arise from the splitting up of the exudation corpuscle. It is more consistent with known facts to suppose that each of these organisms are independent structures, arising

* Gruby, Hunefield, Lechmann, and Messerschmidt, have described the effects of numerous reagents on these bodies, which will be found very useful in any inquiry into their chemical composition. See Henle's Bericht, pp. 187–197.

primarily in the exudation, and are not convertible into each other.

The different isolated corpuscles which have hitherto been described are not necessarily connected with any particular locality or structure. It is undoubtedly true that plastic cells are most commonly found on serous membranes, pus cells on mucous and granulating sores, and exudation cells in dense parenchymatous organs, yet this rule is by no means exclusive. Pus corpuscles are sometimes found in the brain, liver, or on the surface of serous membranes; plastic cells in grey hepatization of the lungs or on the surface of mucous membranes; and exudation cells on the lining membrane of abscesses, or on the surface of mucous membranes and granulating sores. This may probably be dependent on the changes produced by the inflammation itself, which converts one tissue into a structure resembling another. Serous membranes, for instance, owing to the exudation, often resemble mucous, and *vice versa*. Such changes in the situation of the corpuscles, however, are comparatively rare, their seat of predilection being undoubtedly that to which we have ascribed them.

Gruby considers that the varieties in the different products of inflammation described are not so much to be sought in the corpuscles as in the fluid with which they are mixed. Thus, according to him, the corpuscles in mucous or purulent matter do not differ, but the substance in which they are found varies considerably in its consistence and other properties. Now, if we examine a portion of tenacious mucus, such as a person frequently expectorates in the morning, and which is of a greyish dirty colour and tough consistence, it will be found to contain round and oval cells, resembling in size, general appearance, and chemical properties, exudation cells. When, however, as in cases of catarrh, the expectoration becomes abundant and fluid, the corpuscles resemble those of purulent matter. Hence, then, it is true the blastema in one case is more fluid than in the other, but what we are assured of is that the corpuscles are different also. We shall refer to the probable cause of this in a subsequent part of the essay.

Before quitting this subject it is necessary to observe that the three varieties of corpuscles we have described frequently undergo important modifications. What has been said refers to what may be called the type of such formations. In individuals who labour under particular cachexies, as scrofula, syphilis, scurvy, &c., the corpuscles vary more or less in their characteristic properties. We believe, however, that the separation of the three kinds of corpuscles, which distinguish the three great products of inflammation, will facilitate the future study of the differences which these structures occasionally present. This the more so, as, according to our obser-

vations, it is rare that the addition of reagents will not enable us to refer them to one or the other of these divisions.

4. *Of the transformation of the exudation into permanent tissues.* It is a well known fact that after destruction or loss of certain parts they are regenerated, or a substance is formed which acts as a substitute for the tissue removed. For instance, a bone being broken, callus is thrown out and new bone produced. The new tissue thus formed may either resemble the structures in which they occur, or be dissimilar to them, as when a portion of skin is lost a cicatrix is occasioned. As a general rule, very complicated tissues, as the skin, lungs, or brain, are seldom regenerated, whereas, in more simple tissues, as the filamentous, fibrous, or even osseous, this is common. Of the kinds of permanent tissue reproduced the fibrous is the most frequent. It constitutes the cicatrices which replace lost tissues in the skin, lungs, liver, spleen, &c.

The process by which this regeneration of parts takes place is essentially inflammatory; that is to say, an exudation of blood-plasma from the capillaries occurs; this serves as a blastema for the formation of nucleated cells, which become transformed into different structures according to the law of cytogenesis. In the words of Vogel, the process is "the same as occurs in the organization of all the tissues, as observed in the embryo. It is the same whether this organization takes place from fluid or already coagulated exudation. So far as our observation extends, it always follows from a formation of cells. In the exudation arise *nuclei* with *nucleoli*, and these form a cell wall. Thus primary cells are produced, which, according to the general laws of organization, pass by further development into the different tissues, as blood corpuscles, cellular tissue, cartilage, bone, nerves," &c.*

This fact admits of easy demonstration. We have already alluded to the manner in which lymph becomes fibrous tissue. It is by the same process cicatrices are formed throughout the body. If a recently formed granulation on the surface of a healing sore be examined, numerous cells will be observed, of various shapes, and in different stages of development. Some are round, others caudate, spindle-shaped, elongated, or splitting into fibres, exactly similar to the method in which filamentous tissue is produced, as originally described by Schwann, (Fig. 8.) In all cases of hypertrophy a like process takes place; but here the changes are more gradual, and the organization of the exudation is so perfect as to be indistinguishable from the old tissue. In chronic inflammation of the stomach, or in dysentery, we find the muscular coat thickened or hypertrophied, and, on examination, we can demonstrate nucleated bands of non-voluntary muscle increased in thickness, and of great

* Wagner's Worterbuch, Art. Entzündung.

beauty. Hypertrophy of the heart, liver, or other organs is produced by the formation of new and perfectly similar structures to that already in existence. The result of hypertrophy from inflammation is well observed in bones, when, from a blow or local injury, the part becomes thickened, and, on examination afterwards, the new portion is found to be identical in structure with the old.

Much discussion has arisen on the mode in which new bone is formed. Some maintain it can only be produced by bone, whilst others assert it can also be formed by periosteum. Numerous preparations have been grouped together by the supporters of both theories, which prove that both must be right. When a fracture or injury to a bone takes place, it follows that the capillaries of the part injured are inflamed, and an exudation more or less copious is poured out. In this exudation nuclei and cells are formed, which at first resemble those found in cartilage. Bone is subsequently deposited by exactly the same process by which this tissue is developed in the embryo, the vascular membrane, whether external or internal, or lining the Haversian canals in the substance of the bone, as it contains the greater number of capillary vessels, will of course be most active in pouring out the exudation, and thus subserve the purpose of producing new bone. In this way periosteum, bone, or both may form new bone, according as the vascular structures in one or the other are most affected.

When an incision has been made in the skin, blood flows from the divided capillaries, until they are obstructed partly by their own contractility, and partly by the coagulated blood blocking up the cut extremities. The early phenomena of inflammation now manifest themselves, the capillaries become distended and engorged with blood, and at length exudation or the essential phenomenon takes place. After a time, which varies according as the blood more or less abounds in fibrin, the cut surface is glazed as it is called, that is, the exudation has coagulated on the surface, and is transformed into plastic lymph. If now the parts are accurately brought together, little more exudation takes place. Cells are formed, which rapidly pass into a fibrous formation, and healing or *union by the first intention* is the result. When, however, the lips of the wound remain apart, or there has been loss of substance, the exudation is more copious externally than internally. The portion which is infiltrated into the tissue surrounding the sore, constituting the inflamed, red, and indurated margin, is transformed into exudation cells, which, on breaking up, are absorbed. Some of these occasionally find their way to the surface, and become mixed with pus corpuscles,—a circumstance which probably, with some, has supported the supposition, that these structures are different stages of one growth. On the other hand, the exudation which is poured out externally on the surface of the sore is very

abundant, and is transformed partly into the pus cells, and partly into primary cells, which are, by the process of development, converted into fibres, and ultimately constitute the cicatrix. The portions of exudation which are undergoing this process are called granulations. As these become more numerous, the amount of pus diminishes, and a greater tendency is manifested in the exudation to pass into permanent tissue. At length pus ceases to be produced,—the whole exudation passes into fibres,—a new surface is formed,—the which contracting, after a time, constitutes a cicatrix.

In this case a greater amount of fluid exudation is poured out on the surface of the sore, than into the neighbouring tissues, because externally the capillaries are more attenuated, and nothing obstructs the exudation. As new tissue is formed, new vessels are also produced, which in their turn assist in pouring out blood plasma on the surface. Internally the vessels are more uniformly supported by dense tissue, and the amount exuded in that direction is not so great. A section of a granulating sore at this time presents the following appearances.—Among the tissues constituting the edges of the ulcer, there is considerable granular exudation, with exudation cells and masses. The base is entirely made up uniformly of filamentous tissne ; above of cells varying in shape and passing into fibres, and most superficially of purulent matter.

New vessels. It is now well understood that the appearance of vessels in colourless tissues, as in the conjunctiva, is not owing to their being newly formed, but to the over-distension of those which were previously too transparent to be visible. In the exudation poured out on serous membranes or on granulating surfaces, vessels which had no previous existence are produced, and the manner in which this takes place is not yet definitely determined. Two views have been advanced ; 1*st*, That new vessels are formed in connection with the old ones, by the escape of a blood corpuscle, hollowing out for itself a channel in the exudation, which subsequently becomes a vessel. 2*d*, That the new vessel arises independently of the old one, from minute points which become enlarged and afterwards connect themselves with the old ones. This opinion, which was advanced by John Hunter, is most consistent with the researches of Schwann, and the known mode of development of vessels in the embryo. Doellinger and Kaltenbrenner* consider that new vessels may be formed in both stages. Their mode of arrangement in lymph have been shown by the injections of Pockels,† and in granulations by those of Liston.‡ The difficulty of the inquiry consists in ascertaining how the vascular walls are formed previous to that period when

* On the formation of new blood-vessels in lymph, by Dr Allen Thomson, p. 21.
† Idem. p. 28. ‡ Med.-Chir. Trans. vol. v. New Series.

an injection can be thrown into them. The late observations of Mr Travers,* on the injured web of the frog's foot, seem to confirm the first view above-mentioned, whereas those of Hassé, Henle, Skoda, and Kolletscha, on the new vessels of lymph in man, tend to the conclusion that isolated extravasations of blood, channel for themselves passages in the coagulated exudation, which subsequently become vessels, and unite with those previously existing.† These isolated and star-shaped collections of blood I have frequently seen in recently effused lymph, but hitherto have never been able to satisfy myself that they constitute the first formation of new vessels. The whole subject demands renewed investigation.

We have now described the modes in which the exudation becomes organized, and the modifications produced in it to constitute lymph, softening, purulent matter, granulations, cicatrization, &c. To render the account complete it would be necessary to speak of the transformation of the exudation into tumours, and that peculiar modification of it which is known as tubercle. We shall defer the consideration of these subjects, however, until another opportunity. From what has been said it will be seen that the different results which the termination of inflammation in organization produces, may be classified under the heads of temporary and permanent. The temporary structures originating in the exudation, such as plastic, exudation and purulent matter cells, when once fully formed, may be again absorbed. This termination is generally known by the name of Resolution, and it is the process by which this is accomplished, that we have next to consider.

3. The termination of inflammation in resolution.

By resolution has always been understood the disappearance of the inflammation without causing any external lesion. It is best seen in the case of a phlegmonous abscess or bubo, which, being more or less advanced, presenting even a feeling of fluctuation, gradually becomes harder and harder, smaller and smaller, and at length disappears without breaking. In this case the abscess is resolved,—in point of fact, the exudation has been absorbed.

Resolution or absorption of the exudation may occur in various ways, and follow any of the transformations of the exudation except the one which converts it into permanent tissue. The early phenomena first disappear ; the capillaries recover their contractility ; the attraction between the blood and parenchyma ceases ; and the blood within the vessels begins to oscillate, and

* On Inflammation, p. 166.

† Henle's Bericht, p. 206.

at length flows in a continuous stream. *Secondly*, the essential phenomenon disappears, no further exudation takes place, and that already poured out is absorbed.

It occasionally, though rarely happens, that the exudation does not coagulate for some time after it is exuded. Under these circumstances, when the early phenomena terminate, it re-enters the vessels by endosmosis, unchanged. In the majority of cases, however, it coagulates, and once rendered solid, it could never be absorbed, without the occurrence of changes in it, by which it is again rendered fluid. This is effected by the formation, ripening, and disintegration or decay (moulting process, Schulz,) of nucleated cells, whereby the coagulated exudation is broken up, made soft, pultaceous, and diffluent, and at length absorbed. It is by this process that exudation poured out into the lung or brain gradually disappears, by the production of inflammatory softening, such as we have previously described it. On the serous surfaces, the fluid and broken down corpuscles are absorbed; but that portion which passes into permanent organization is transformed into fibrous tissue, becomes covered with a smooth membrane, so that the functions of the organ are not disturbed. Abscesses when resolved undergo a similar process.* The pus cells, instead of being evacuated, are brought closer together, from the absorption of the more fluid portion (*liquor puris*). These are gradually broken down, the cell walls are dissolved, and the whole is reduced to a molecular matter, which re-enters the vessels, and thus complete resolution is produced.

The disintegration of pus corpuscles previous to absorption is evidently favoured by the pressure which the abscess receives from the contraction of the filamentous and elastic tissues that form its walls. This is shown by the increased hardness which always accompanies the disappearance of suppuration by resolution, and the good effects which result from direct pressure employed by the surgeon to discuss these swellings. In Berlin, the most successful treatment for bubo consists in simply placing a stone of one or two pounds weight over the tumour in the groin, as the individual is laying on the back. It is probable, also, by increasing the contraction of the integuments, as well as by removing fluid from the neighbourhood of the part, that irritants, blisters, and cauteries are so beneficial in the resolution of abscesses.

It is suggested by Zimmerman that the formation of an acid, as the lactic, in abscesses when fully formed, favours their disintegration. We have seen that acetic acid dissolves the cell

* "I have seen cases in which pints of matter have been taken up in psoas abscess, and the parietes remain without breach."—*Travers on Inflammation*, p. 186.

wall, and causes the nucleus to appear in the form of granules. If lactic acid be produced it would probably have the same effect. Alkaline solutions also, it is well known, dissolve pus corpuscles,—a circumstance that may explain the discutient effects of alkaline lotions and washes, and their beneficial operation in removing the incrustations from eruptive pustular diseases.

The next point to determine is, what becomes of the molecular fibrine, which thus re-enters the circulation? On this subject the observations of several German physicians, more especially of Schönlein and Zimmerman, have thrown much light. They have observed with great care the changes which the urine undergoes in acute inflammatory diseases, and determined that these changes bear a relation to the absorption of exuded blood plasma in internal organs. Thus in a case of pneumonia, which I watched in La Charité Hospital, Berlin, under Schönlein in 1841, he pointed out that the disappearance of dulness was accompanied by a turbid state of the urine, which contained a large amount of molecular fibrine, and was also highly coagulable by heat. Similar results have been frequently observed in the clinical wards of Schönlein during the resolution of pleuritis, erysipelas, small-pox, abscesses, and other diseases. M. Martin-Solon, in his work de l'Albuminurie, 1838, observes, that in a great number of instances of acute febrile and inflammatory diseases, such as ague, typhus, measles, small-pox, febrile urticaria, pneumonia, gout, rheumatism, and inflammation of serous membranes, he has remarked that the urine for some days about the period of crisis yields a more or less abundant precipitate, which is owing to a superabundance of lithate of ammonia.* Zimmerman more especially has recorded instances where the turbidity and coagulability of the urine bore a marked relation to the diminution of suppurative swellings. In some cases where purulent matter was apparently absorbed, he had observed that the urine was coagulable from the presence of fibrin dissolved in it.† In a case of pleuritis, and another of pneumonia, where this change in the urine was observed, the blood also was found to contain an excess of fibrin.

These observations have led to the conclusion, that the molecules of the broken up exudation, after circulating in the blood, are frequently eliminated by the kidneys, and make their exit from the system by the urine, sometimes entire, at others in a state of solution. This conclusion is confirmed by a number of pathological and chemical facts, and may be considered esta-

* See Christison "On the Granular Degeneration of the Kidnies," p. 42.
† Casper's Wochenschrift, 1843.

blished. Occasionally the excess of fibrin may be eliminated by the skin, lungs, and bowels. In all cases it constitutes an important symptom of the crisis.

The morbid disposition in urine is not always the same. It is very probable that the fibrin, whilst circulating in the blood, undergoes certain changes of a chemical nature. According to Liebig, the oxygen of the blood converts the fibrin into urate of ammonia, choleic acid, sulphur, phosphorus, and phosphate of lime. Each of these undergo further changes. The urate of ammonia, by the farther action of oxygen, is converted into urea and carbonic acid; the choleic acid into carbonic acid and carbonate of ammonia; the sulphur and phosphorus into sulphuric and phosphoric acids, which, combining with an alkali or earth, form sulphates and phosphates. If it should happen that the quantity of oxygen taken in is not sufficient completely to accomplish this cycle of changes, then, instead of urea, either urate of ammonia appears in the urine, or, if the ammonia have entered into any other combinations, pure crystals of uric acid or fibrin.* In this manner we can comprehend how, after the resolution of acute inflammatory diseases, different sediments appear in the urine from the conversion of the excess of fibrin contained in the blood.

Mulder has lately shown, that the buffy coat in inflammatory blood is an oxide of fibrin. Now, it may be asked, does this excess of oxygen attach itself to the fibrin already in the blood and precede inflammation?—or does it combine with the fibrin reabsorbed after exudation has taken place? I am inclined to suppose the latter, for it is difficult to explain how the blood should receive a relative increase of fibrin before inflammation, or, as we have endeavoured to express it, its essential phenomenon, exudation, has taken place. When, however, we know that the fibrin which has been coagulated in the parenchyma of the lung in pneumonia is, after a time, re-absorbed, the presence of an increased amount of that principle in the blood is easily accounted for. We are far from wishing to attribute the whole of the increased fibrin to this source. A similar change has been observed in the mass of the blood under circumstances where the local symptoms were comparatively trifling, and where the lesion was incapable of furnishing the amount of fibrin formed, as in amygdalitis for instance. In such cases, however, according to Andral and Gavarret, the increased quantity of fibrin was small. At all events, it appears by no means improbable that the amount of fibrin thus absorbed, added to the amount previously existing, may so sur-

* Simon's Beitrage, p. 536.

charge the vital fluid that its excretion by the emunctories becomes visible.

Of secondary purulent formations.—In a former part of this essay, we stated that no one who had examined the blood corpuscles on the one hand, and the capillaries on the other, could conceive the possibility of the former passing through the latter if both structures were in a state of integrity, and that all observation was opposed to such a supposition. In like manner it is impossible that blood or pus corpuscles could pass backwards into the vessels. How, then, it may be asked, do the metastatic abscesses, or secondary depositions of pus, as they are frequently termed, which follow severe wounds and injuries, take place? Similar observations to those we have just alluded to, indicate two modes in which this occurs. Either the broken down pus corpuscles when absorbed are again deposited in other organs, and, conjoined with fresh exudation, constitute the blastema for a new formation of pus, or they pass unchanged through lacerations in vessels large enough to receive them, become obstructed in the minute capillaries, and then produce inflammation and suppuration.

The same observations to which we have previously alluded, respecting the absorption of the exudation in a molecular form in pneumonia, pleuritis, abscesses, &c., also indicate the possibility of the molecules being occasionally deposited in other organs when anything occurs which obstructs their excretion through the kidneys. It is certainly difficult to prevent hypothesis from entering into our consideration of this subject, because, hitherto, observations of the state of the blood and of the urine have been very few in such cases. We may readily understand, however, that if the excess of fibrin does not pass off in the urine or some other discharge, it may be deposited in a molecular form in other tissues, and there constitute a blastema, in which (perhaps conjoined with fresh exudation) collections of pus corpuscles arise. In this manner a secondary inflammation followed by suppuration may be occasioned.

Gruby states that the corpuscles found in a metastatic abscess are destitute of cell walls. Afterwards, according to him, an inflammation arises around the metastatic infiltration; *new* globules of pus with an envelope, molecules, and a central vesicle, shortly arise; so that even here and there, in a metastatic abscess, globules of pus with an envelope are to be detected. This, in our opinion, is tantamount to saying, that pus corpuscles are formed in the granules of the exudation deposited.

Secondary purulent formations, however, are most common results of severe injuries, such as compound fracture or lacera-

tion of parts. In such cases a large number of vessels are torn across, and we can readily understand, that if the exudation or lymph which ought to obstruct these vessels, instead of passing into permanent tissue, become transformed into pus, that the corpuscles will have a direct and ready entrance into the circulation. We shall afterwards see that a rapid and large amount of exudation, as occurs in such cases, favours this result. Zimmerman supposes that the pus already formed dissolves the coagula, which obstruct the vessels. Perhaps it would be more correct to say, that, instead of passing into tissues, the coagulated blood plasma forms a blastema for the formation of numerous corpuscles. That, under certain circumstances, this occurs even within the vessels, has been shown by Gulliver,* and I have satisfied myself of the correctness of his statements by direct observation.

In a man who died after amputation of the thigh, under Mr Syme in the Royal Infirmary, I carefully dissected out the femoral vein and its principal branches leading from the stump. In slitting up the main trunk, I found it entirely filled with a coagulum, which, in the portion of the vessel passing under Poupart's ligament, was very firm; but, on tracing it downwards, its consistence was found to diminish. About the middle of the thigh it was broken down and soft, and, towards its termination, became diffluent. That this was not a mechanical softening was proved by a careful microscopic examination. Superiorly the clot only contained the minute primitive filaments found in colourless coagula. Further down these became mixed with plastic and exudation corpuscles. The latter were very numerous at a portion of the vessel which was somewhat constricted. As the examination proceeded lower, the corpuscles became more numerous, and the filaments disappeared, until at length nothing but corpuscles, innumerable filaments, and the fluid in which they swam, were present. In another case, of heart disease, where two small tumours the size of filberts were found attached to the mitral valves, I found internally numerous exudation and pus cells. The character of the latter were determined by the peculiar nuclei which were made apparent on the addition of acetic acid. In both cases it is evident that corpuscles had been formed in the coagulum.

Now, in cases of severe injuries, it is very probable that a similar process goes on, not only in the exudation thrown out, but in that portion of it which, under other circumstances, would have closed up the ruptured vessels. Pus, then, directly enters the vessels, and is carried into the torrent of the circulation. What now happens may be well described in the words

* Gerber's Anatomy, note, p. 31.

of Zimmerman. "If the entire pus corpuscles have been taken up by the venous system, they either reach the heart and pulmonary artery into the capillary structure of the lungs, or, in case the purulent deposition was seated in organs whose veins formed the *vena portæ*, they reach through these into the capillaries of the liver. Now, as the pus corpuscles are in general too large to pass through the fine capillary net-work in the lungs and liver, it is evident that, for this reason, they must begin to stop here, to accumulate, and to occasion a stasis as foreign irritants. These, then, form new pus depositions, which progressively become greater from the constituents of the blood, and of the parts of the tissue capable of it. From this simple cause, it is easily explained why secondary abscesses form so readily in the liver and lungs. If the pus deposited in the liver, and newly formed, be taken up by the hepatic veins, these bring it into the heart and into the lungs. If it be taken up from these by the pulmonary veins, it may be deposited in every other organ to which the blood comes from the left ventricle. In this case secondary abscesses may form in the brain, in the kidneys, in the spleen, &c. and pus may even be discovered in the urine.*"

Purulent matter formed within the vessels, the result of arteritis or phlebitis, produces similar results in a like manner.†

* See translation of Zimmerman's paper, Med. Chir. Review, July 1844, p. 152.
† See translation of Gruby, Obs. Micros. Journal, Vol. ii. p. 266.

VII.—THE CIRCUMSTANCES WHICH INFLUENCE THE TERMINATIONS OF INFLAMMATION.

It becomes very important to inquire what are those circumstances which induce the different transformations of the exudation, such as we have previously described them, and when we may expect lymph, softening, suppuration or permanent tissue to follow the inflammatory process. A satisfactory elucidation of this subject must be intimately connected with our mode of treatment, inasmuch as a knowledge of those circumstances which favour or retard one more than another, will enable us in particular cases to apply our remedies so as best to assist the intentions of nature.

It at once becomes evident that the essential cause of organization lies in the vitality and peculiar properties of the exudation itself. This, like every blastema, as the egg in animals or the seed in plants, possesses the power of development, and passes into organization when placed in circumstances favourable to growth. It is not connected with the causes of the inflammation, as these, however various, whether chemical, mechanical or vital, give rise to similar results. The origin of this function, therefore, must be sought in the vital properties of the exuded blood plasma alone. The same general circumstances also influence the development of the exudation as influence organization in every species of blastema, whether vegetable or animal. The most important of these are temperature, the presence of moisture, and certain changes of the atmosphere.

That temperature exercises a most powerful influence on the growth of plants, that is, on the development of the cells of which they are composed, is a well-known fact. All vegetation requires a temperature between 0° and 100° Fahrenheit. It is also well established that vegetation is more rapid in elevated than in low temperatures, and horticulture teaches us that its proper regulation will enable us to accumulate within a small compass the plants of every clime. The importance of temperature in the growth of animals is equally well marked, and may be observed in the process of incubation, and the care with

which the mother instinctively guards her young from the approach of cold. Even in man, the fact that he attains maturity earlier in warm than in cold climates, is only a further illustration of the same general law. Growth, as we have seen, only consists in the evolution and further development of nucleated cells, and the same laws which apply to this process in plants and animals in a state of health, apply to them in disease.

It has long been recognized in practical medicine, that cold and heat locally applied, are amongst the most powerful means of combating inflammation. It is well known that the first checks the inflammatory action, and retards the formation of pus, whilst the last favours the passage of the exudation into suppuration. This is only acknowledging that cold checks, whilst heat facilitates the passage of the exudation into nucleated cells. In short, for the same reason as the horticulturist who wishes to bring forward a plant, places it in a hot house, so the surgeon who desires to bring on suppuration applies hot poultices and fomentations. From these considerations the indications for the especial application of cold and heat in inflammation may be at once deduced.

That moisture is as necessary for growth as a certain temperature may be proved from like observations in plants and animals. I need not allude to the necessity of supplying water in order to secure the growth of the former, or to the circumstance that in every ovum a fluid surrounds the yolk, or portion where nucleated cells are actively developed. In the same manner we have seen that a rapid exudation and consequent excess of fluid favours the evolution of isolated cells, as those of pus or of plastic lymph, whilst its diminution is more favourable for more permanent growths. The formation of pus seems to be more especially favoured by the constant addition of fluid, and hence probably its common occurrence in all those situations where this takes place, as from the walls of abscesses, the surface of mucous membranes, ulcers, &c. For this reason suppuration is impeded, and union by the first intention favoured, if, before uniting the edges of incisions, we wait till the extravasation of blood has ceased, and exudation has occurred. Hence may be explained the practice so long prevalent in the Edinburgh School of Surgery of not sewing together the flaps till some hours after amputation, and glazing has taken place. On the other hand, moist applications conjoined with heat have been found most favourable for advancing suppuration.

It was supposed by Hunter that the presence or absence of atmospheric air exercised an influence on the results of inflammation. To the seclusion from air he ascribed the production of lymph, as in shut cavities, whilst that of pus, according to

him, is favoured by an exposure to it. A free surface, as exists on the skin or mucous membranes, as they favour an effusion of serum or excess of moisture, so they naturally favour the passage of the exudation into pus or isolated cells. Hence, probably, the entrance of air into large abscesses, so much dreaded by surgeons, is not injurious from any poisonous influence it exerts, as from the circumstance that it keeps the walls separate, and thus favours an excess of exudation and organization.

That changes in the atmosphere, independent of temperature and moisture, exert a powerful influence in advancing, impeding, or destroying growth, becomes evident on paying attention to its effects throughout all animate nature, vegetable as well as animal. Crops which have called forth the utmost skill of the agriculturist, and which seem to promise the best return, slowly or suddenly become withered; their further growth is checked, and they die, and this not owing to any fault in the soil or in the nature of the seed, but to some yet undiscovered change existing in the atmosphere. So in particular seasons of the year, or in certain localities, we observe epidemic or hospital gangrene, and witness the same exudation which, under other circumstances, would become organized, together with the structures involved in it, &c. become mortified and thrown off from the economy. Of the nature of this atmospheric influence or malaria we know nothing, but that it exists, observations such as we have alluded to sufficiently prove.

Why the exudation should not always undergo the same transformations or pass into the same organization, it becomes very difficult to determine. The blood plasma exuded throughout the body, when first poured out, is, in all tissues, essentially the same, and yet we see plastic, exudation, and pus cells formed in it, and frequently cellular tissue, bone, or other structures. Occasionally we see the same exudation partly transformed into pus, and partly into permanent tissue, as on the surface of an ulcer. All that can be said on this subject appears to be, that the same vital laws, which, in a healthy state of the economy, produce from the same blastema nucleated cells, passing into fat, muscle, nerve, bone, and so on, induce, in a state of disease, results equally dissimilar from the same cause. Both research and observation, however, indicate that there are certain circumstances connected with the *individual* which exert a considerable influence in determining the kind of organization which takes place in the exudation. These circumstances appear to be connected, 1*st*, with the elementary structure of the tissue; 2*d*, with the vital power of the whole organism; and, 3*d*, with the progress of the inflammation. As these are points of great practical importance, I shall shortly consider each in succession.

1. The surrounding elementary structures exercise an evident influence on the further developement of the exudation. Thus, blood-plasma effused in the neighbourhood of cellular tissue, is again developed into cellular tissue, as we see in granulations, in the greater number of regenerations and healing of wounds. Exudation in the immediate neighbourhood of bones, or into their substance, is changed into bone. Even the primitive fibres of nerves have been said to be capable of regeneration when once divided. Serous membranes, shut sacs, with vessels and epithelium, may be newly formed from exudation effused on serous surfaces. Every tissue is capable of being hypertrophied, when the exudation is poured out slowly, as in chronic inflammations. In all these cases the new pathological formation depends apparently upon the influence the surrounding parts possess over the other circumstances which govern the developement of the exudation.

2. The vital power of the whole organism has a most undoubted influence over the further development of the exudation. When inflammation is followed or accompanied by general loss of strength, it does not become organized, or is very imperfectly so. In such cases the exudation breaks down into an undetermined granular mass, although it sometimes exhibits an imperfect tendency to cell formation. Diminished energy of the vital power, therefore, or certain changes in the constitution of the blood, tends to reduce and destroy the further development of the exudation. This is very well observed in scrofula, in which disease, whilst the fibrin of the blood is diminished, the albumen is in excess. Here, when suppuration takes place, it occurs slowly, and the pus cells are found to be imperfectly developed. Instead of being round and rolling freely on each other, they are angular, collect into masses, and are mixed with numerous granules. In parenchymatous organs, the occurrence of tubercle is common, which consists of numerous granules, with a few imperfect attempts at cell formation. In syphilis, scurvy, and other cachectic constitutions, it is well known that the exudation passes very slowly into organization, and that it frequently dies, causing ulceration. Moreover, the difficulty with which fractures and wounds heal in individuals badly nourished, in old age, or in such as labour under putrid diseases, as typhus or jail fever, sufficiently demonstrate the influence of the general vital powers on the development of the exuded blood plasma. *

3*dly*, The rapidity with which the exudation takes place, and its amount, exercises a powerful influence on its organiza-

* May not the difficulty with which wounds heal by the first intention in Paris, be ascribed to a constitutional cause?

tion. When the inflammation is acute, when the exudation occurs in considerable quantity, and the power of the constitution offers no check to the development, it passes readily into exudation, plastic and pus cells, and if there be loss of substance this is quickly restored. The quantity and quickness of the exudation favours its transformation into one of the three kinds of isolated corpuscles, according to the texture of the part. On the other hand, when the inflammation is chronic, and the exudation is poured out slowly or in small quantity, it possesses an evident tendency to pass into a higher state of organization, and the cells are developed into fibres, or some of the permanent tissues. Hence union by the first intention from the small quantity of the exudation—union by the second intention from the slow progress of the organization, that which takes place rapidly being thrown off in the form of pus. Hence also the slow formation of adhesions and dense membranes in shut cavities. Lastly, when the exudation is poured out with great slowness, tissues are formed which are identical with those existing in a normal state, giving rise to hypertrophy in different organs. In this manner the violence of the inflammation and amount of exudation exert a great influence over the products produced, as has been long recognized in pathology by the terms adhesive inflammation, suppurative inflammation, &c.

Such, then, appear to be the more important circumstances which influence the terminations of inflammation.

We have now endeavoured to describe the principal phenomena which characterize the inflammatory process, and the manner in which its products are produced. The early phenomena, consisting of contraction, succeeded by dilatation of the capillaries, are analogous to what are called spasms and paralysis in the muscular tissue. The enlargement of the vessel permits a greater quantity of blood to enter it, whilst its corresponding increase of tenuity permits fluids to be exuded through its walls, which, in a state of health, were retained. This increased exosmosis, the approach of the yellow corpuscles to the sides of the vessel, and the stoppage of the blood, we endeavoured to show, could only be explained by supposing the existence of a vital power causing an increased attraction between the blood and surrounding parenchyma. This hypothesis is, of course, only intended to express a certain series of facts, in the same manner that we speak of electrical attraction and repulsion, or of gravitation, as explanatory of well-known occurrences.

The early phenomena may be followed by the extravasation of blood, by the effusion of serum, or the exudation of blood-plasma. The latter constitutes the essential phenomenon, and is in-

variably present, serving to distinguish inflammation from mere congestion and all other morbid processes.

The blood-plasma exuded, and the textures imprisoned in it may die and pass into decomposition, rapidly, constituting mortification, or more slowly causing ulceration. On the other hand, it may assume an active power of growth, in which case different kinds of nucleated cells are formed, which either remain isolated or pass into organization of tissue. Inflammatory softening is caused by the formation of exudation cells; organizable lymph by the formation of primitive filaments, mixed with plastic corpuscles, and suppuration by the formation of purulent matter corpuscles. When there has been loss of substance, the exudation passes partly into purulent matter and partly into cellular tissue, and sometimes into other elementary textures. This, however, always by the process of cytogenesis. Occasionally the exudation is absorbed, either directly before its coagulation, or more commonly after this, by the disintegration of the isolated and temporary corpuscles which are formed, so that the coagulated blood-plasma is again rendered fluid and molecular, and capable of re-entering the vessels. These different results constitute the subsequent phenomena, or terminations of inflammation.

Lastly, we have seen that the vitality of the exudation is influenced by the existence of a medium temperature, moisture, and the state of the atmosphere, and that the kind of organization into which it may pass is dependent, 1*st*, On the elementary structure of the tissue in which it occurs; 2*d*, By the vital power of the whole organism; and 3*d*, By the progress of the inflammation.

VIII.—CONCLUDING REMARKS.

Before altogether closing our consideration of the pathology of inflammation, it will be well to allude to one or two points which we may now discuss with some hope of arriving at a satisfactory conclusion. One of the first pathologists, and one of the first physiologists in Europe, viz. Andral and Magendie, have both declared that the word inflammation should be banished from medical nomenclature, "created," says Andral, "in the infancy of science, this expression altogether metaphorical, was destined to represent a morbid state, in which the parts appeared to burn, to be inflamed, &c. Received into general language without any precise idea having ever been attached to it, in the triple relation of symptoms which announce it, of the lesions which characterize it, and of its intimate nature, the expression inflammation is become so very vague, its interpretation is so very arbitrary, that it has really lost its value, it is like an old coin without an impression, which ought to be removed from circulation, as it only causes error and confusion. Magendie remarks, "when we are called upon to pronounce the word inflammation, it is rather to criticize it than to attach to it any definite ideas." Again he says, "one could fill an entire book with all the ideas which represent the word inflammation, for it is synonymous with the word disease."

Andral, after having pointed out the confusion resulting from the term inflammation, has replaced it by the word *hyperæmia*, or excess of blood. We evidently, however, gain nothing by this substitution, as it is one of words, not of ideas, and the term congestion, already in use, is synonymous with it. Magendie, in ridiculing the word inflammation, has never attempted to replace it in any way. Eisenmann has endeavoured to substitute the word *stasis*. But this only means stoppage of the blood, and may take place in the veins as well as in the arteries, without exciting any of the phenomena called inflammatory. Hence it has been the object of British pathologists to give precision to the old term inflammation, rather than change it for another, perhaps more unsatisfactory.

It is evident, however, that the symptoms of pain, heat, redness, and swelling, are no longer sufficient to indicate inflamma-

tory action. All these may depend upon simple congestion alone, and they may all be absent even when an inflammation has been sufficiently powerful to destroy life, as in the substance of the brain. Neither can we any longer retain the vague ideas which exist with respect to its pathology. Most pathologists, indeed, on being questioned, are obliged to acknowledge that of this they know nothing, and practical men, though they profess themselves capable of detecting its existence, are all ready to confess their ignorance of its nature.

One of the most powerful opponents of the ideas of Andral and Magendie, is the present distinguished Professor of the Practice of Physic in this University. Dr Alison says " A peculiar perversion of nutrition or of secretion, we hold to be essential to the very existence of inflammation; and all descriptions, and all attempts at explanation of the changes to which the term is applied, if they do not include this, their most essential peculiarity, we must regard as necessarily and fundamentally defective." * Now it is this perversion of nutrition that I hold we must regard as the principal feature in all the phenomena of inflammation. In order, however, to understand what is meant by perversion of nutrition, it evidently becomes necessary that we should have a clear idea of what is meant by healthy or normal nutrition.

We have taken great pains to point out that a healthy nutrition consists, 1st, in a healthy state of the blood; 2d, in a healthy exudation of blood-plasma; and 3d, in the formation of nucleated cells, passing into the healthy structures of the organism, as fat, bone, muscle, and nerve. In inflammation, however, we have seen that there is, 1st, an unhealthy state of the blood; 2d, an unhealthy exudation of blood-plasma; and 3d, a formation of nucleated cells, passing into structures foreign to the organism, as softening, lymph, purulent matter, and cicatrix. Surely, then, we are warranted in saying that inflammation is nothing more or less than a form of anormal nutrition.

Dr Alison further observes, " It is true that the various effects which we ascribe to inflammation, adhesion, suppuration, ulceration, and gangrene, are very different from one another, and that we cannot satisfactorily point out the cause or even the mode by which each is effected." It is hoped, however, that in the preceding pages, not only has a sufficient cause been adduced, but that the mode in which the different terminations of inflammation are produced has been described from actual observation. That is, in the same manner that Schleiden in plants, and Schwann in animals, have indicated the steps of normal nutrition, owing to the formative influence of a vital blastema, so it has been endeavoured to point out the mode in which anormal nutrition acts

* Lib. of Medicine, p. 53.

in producing the various results of inflammation, from the transformations of the exudation.

It may be thought by some that this doctrine contains nothing new,* that many authors have said the same thing; that Andral, Lobstein, and numerous others in their works on pathology, have distinctly spoken of increased and diminished nutrition ; and that the term morbid growths, as applied to tumours, is a sufficient proof of this. No doubt the idea of a morbid nutrition has occurred to writers on pathology, yet how have they applied such ideas to the phenomena of inflammation ? So far from their having conceived purulent matter to be connected with this process, they supposed it to be secreted from the blood, in some unknown way, in order to be removed from the system. That is to say, they classified pus with the bile, urine, milk, and sweat, fluids secreted by glands to be excreted from the body. They had no idea that purulent matter was the result of an active process of nutrition, formed and developed in exuded blood-plasma as from a blastema. Even an authority so late as Gerber describes the pus corpuscle as being formed by the breaking up of the exudation cell, and Travers speaks of lymph being the secreting organ of purulent matter.† No one has clearly distinguished the difference between the cells found in pleuritic lymph and those of purulent matter, although the former have been accurately figured by Gulliver and Vogel. Again, inflammatory softening was confounded with that lesion which is the result of maceration, and no means existed of distinguishing one from the other. The identity between exudation corpuscles and the granular bodies of the colostrum was not known.‡ In short, it was utterly impossible that, before the doctrine of growth by cells, they could have formed the most remote conception of the manner in which these morbid appearances were produced. Even the steps of healthy nutrition were unknown ; how, then, could they explain the morbid phenomena ? Their hypothesis, however, remained, and as so often occurs in the history of science, what at one period was the merest hypothesis, and only the offspring of a luxuriant imagination, becomes confirmed by observation, and, after a time, received as established truth. I shall be satisfied if, in the foregoing essay, the mode in which this anormal nutrition takes place has been clearly shown, and the various phenomena of inflammation satisfactorily demonstrated to be explicable according to the present state of science.

It may further be objected, that the term anormal nutrition, if

* My first paper on this subject was read to the Medico-Chirurgical Society of Edinburgh, November 1842, and an abstract of it was published in Cormack's Journal for December following. It is referred to by Henle in his Report, p. 198.

† On Inflammation, p. 122.

‡ See Wagner by Willis, p. 429.

correct, can only affect the results of inflammation, and not inflammation itself. But what is inflammation unconnected with exudation? Dr Alison directly tells us that he can form no idea of inflammation unconnected with effusion. If we take away the results, we have only congestion or the early phenomena remaining, to which we can never apply the term. But it is evidently erroneous to split one process into two; and to call the first part the cause and the other the result. Besides, where shall the division be made? Who has ever thought in healthy nutrition of making such distinctions? The whole is one process, consisting essentially in the exudation of blood-plasma, and of its subsequent transformations, and so it is maintained in anormal nutrition; the exudation and subsequent changes are one process also.

If, however, the word inflammation must be used, (and it may be questioned whether the time has yet arrived for removing it altogether from practical medicine,) it must be limited to that series of actions which terminates with the exudation of blood-plasma in unusual quantities.. In this sense it may always be employed with propriety, and we may always understand by it that a congestion has terminated in exudation, which may die, or become organised, be absorbed, or pass into permanent tissue, according to those vital laws which govern normal as well as anormal nutrition.

Description of the Plate.

Fig. 1. An exact copy of a portion of the web in the foot of a young frog, after a drop of strong alcohol had been placed upon it. The part was illuminated by the reflected light of day, and considerable pains have been taken to imitate the colours, such as were then presented. The view exhibits a deep-seated artery and vein, somewhat out of focus; the intermediate or capillary plexus running over them, and pigment cells of various sizes scattered over the whole. On the left of the figure the circulation is still active and natural. About the middle it is more slow, the column of blood is oscillating, and the corpuscles crowded together. On the right congestion, followed by exudation, has taken place, constituting inflammation of the part.

a. A deep-seated artery, out of focus, the rapid current of blood allowing nothing to be perceived but a reddish, yellow broad streak, with lighter spaces at the sides. *b*. A deep-seated vein, partially out of focus. The current of blood is of a deeper colour, and not so rapid as that in the artery. It is running in the opposite direction. The lymph space on each side, filled with slightly yellowish blood plasma, is very apparent, containing a number of colourless corpuscles, clinging to or slowly moving along the sides of the vessel. *c*. In the portion of capillary plexus included within this bracket the circulation is still active and natural. The normal amount of yellow and colourless corpuscles are seen within them. *d*. In the portion of capillary plexus included within this bracket, the yellow corpuscles are crowded together, and the column of blood is oscillating. At *e*, this oscillation is very slight. At *f*, the corpuscles are pushed forwards and backwards to the extent of half an inch. At *g*, laceration of a capillary vessel has produced an extravasation of blood, resembling a brownish-red spot.

At *h*, some of the yellow corpuscles less aggregated together are observed. *i*. In the portion of capillary plexus included within this bracket, congestion has occurred, and the blood corpuscles are apparently merged into one semitransparent, reddish mass, entirely filling the vessels. The spaces of the web, between the capllaries, are rendered thicker and less transparent, partly by the action of the alcohol, partly by the exudation. This latter entirely fills up the spaces, as at *k*, or only coats the vessel, as at *l*. At *m*, a portion of the external epithelium is brought into focus, exhibiting its peculiar cells with their nuclei. These nuclei will be observed to resemble the colourless corpuscles of the blood, for which they have been by some mistaken.

Fig. 2. Primitive filaments in a portion of semitransparent lymph exuded on the surface of the pleura. These delicate filaments will be observed in some places to be molecular, and to contain here and there minute granules.

Fig. 3. Primitive filaments and plastic corpuscles, from a portion of opaque lymph, recently exuded on the pleura. The filaments are here stronger and more densely crowded together.

Fig. 4. Plastic corpuscles with epithelium cells. From gray hepatization of the lungs. *a*. Appearance after the action of acetic acid.

Fig. 5. Isolated cells, of various forms and in different stages of development, passing into fibres. From minute vegetations encrusting the base of the mitral valve.

Fig. 6. Similar cells, from lymph exuded on the pleura.

Fig. 7. Similar cells. Both isolated and in mass, from a layer of lymph on the peritonæum.

Fig. 8. Similar cells, from healthy granulations following a burn.

Fig. 9. Exudation in a finely granular or molecular state, with nuclei apparent, coating a vessel. Found in cerebral softening.

Fig. 10. Exudation granules and cells, coating a vessel. From a portion of inflamed placenta.

Fig. 11. Exudation granules and cells, filling up the interstices between the vessels. From a portion of inflamed brain. The addition of acetic acid has rendered the vascular walls transparent and their nuclei apparent.

Fig. 12. Exudation corpuscles from the brain. *a*. Exudation mass.

Fig. 13. Exudation corpuscles and masses, commonly called granular bodies of the colostrum. From diseased human milk, secreted some days after parturition.

Fig. 14. Corpuscles in thick viscid mucus, expectorated early in the morning by an individual in good health. Molecular filaments and granules are also apparent.

Fig. 15. Tabular view, showing the action of water and acetic acid on the plastic, pus, exudation, and colourless blood corpuscles.

EDINBURGH: PRINTED BY STARK & COMPANY, OLD ASSEMBLY CLOSE.

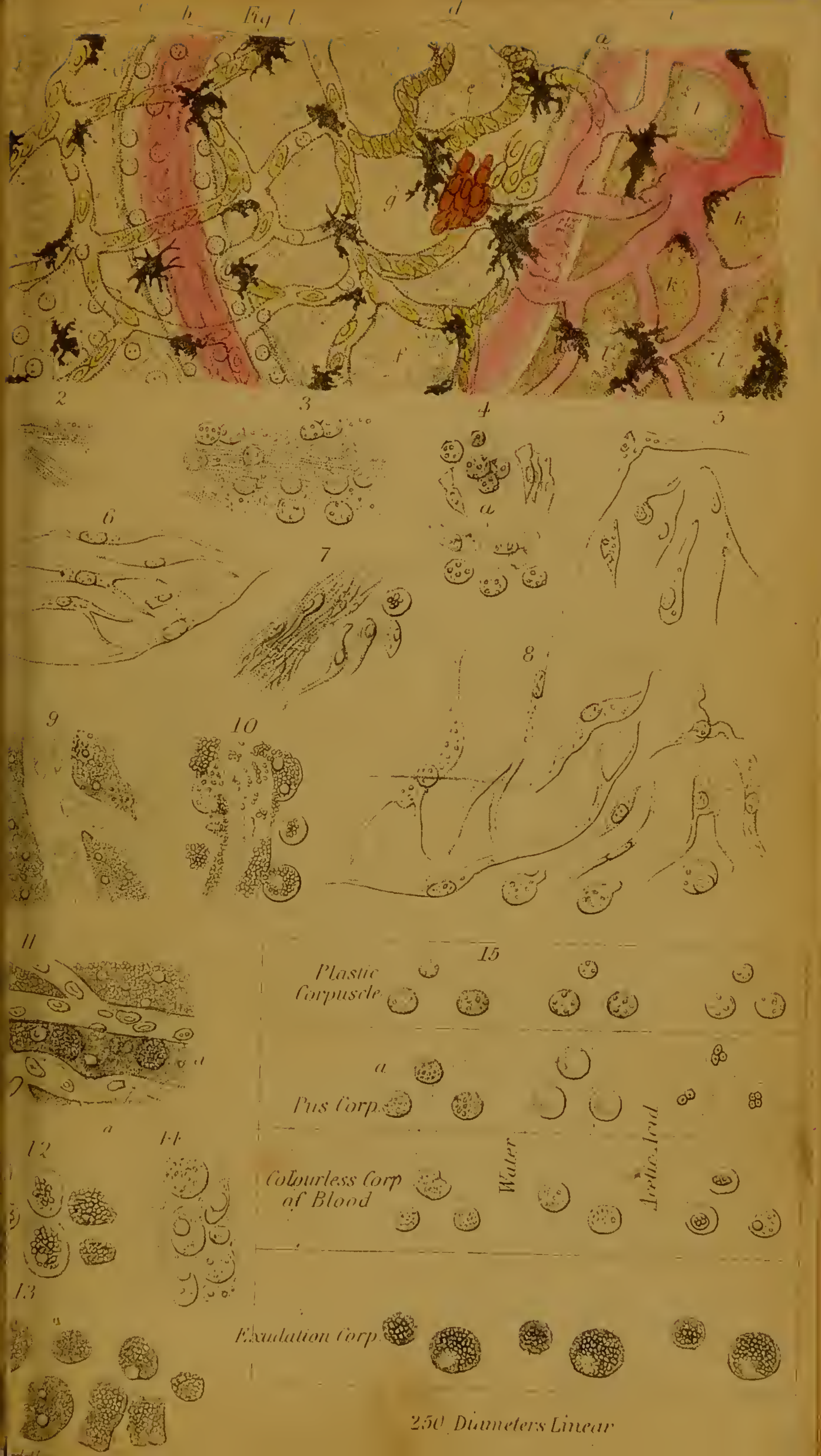
Fig 1.
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Plastic Corpuscle
Pus Corp.
Colourless Corp of Blood
Water
Acetic Acid
Exudation Corp.
250 Diameters Linear